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OUTLET WORKS FOR LOST CREEK DAM, ROGUE RIVER, OREGON. HYDRAULIC--ETC(U)
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TECHNICAL REPORT NO. 140-1

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OUTLET WORKS FOR LOST CREEK DAM
ROGUE RIVER, OREGON

HYDRAULIC MODEL INVESTIGATIONS

OCTOBER 1979

SPONSORED BY
U.S. ARMY ENGINEER DISTRICT
PORTLAND

CONDUCTED BY
DIVISION HYDRAULIC LABORATORY
U.S. ARMY ENGINEER DIVISION, NORTH PACIFIC
CORPS OF ENGINEERS
BONNEVILLE, OREGON

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Two 1:40-scale hydraulic models were used to study the outlet works for Lost Creek Dam. One model reproduced a portion of forebay, the selective withdrawal intake tower, regulating outlet valve section, tunnel, chute, energy dissipator, penstock intake and curve, powerhouse, and a section of downstream channel. The other model reproduced the tower bypass system. The intake tower, tunnel and penstock intakes, and penstock curve were satisfactory with all operating conditions observed. The transition from the tunnel to the chute was not cont'
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20. ABSTRACT (Continued)

CONT

adequate with the highest discharges, and wave suppressors were added to the walls to create satisfactory flow conditions in the chute. The original energy dissipator, a shallow hydraulic jump stilling basin, was not adequate and was replaced with a 30-degree, 50-ft-radius flip bucket because a minimum amount of rock excavation was desired. The tower bypass system was satisfactory with the design condition of 2,100 cfs and minimum pool elev 1826 but not satisfactory with a design flow of 1,050 cfs and minimum pool elev 1789. Only flows less than 700 cfs could be passed with pool elev 1789 without possible vortex problems.

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PREFACE

Hydraulic model studies of the intake tower and regulating outlet for Lost Creek Dam were authorized by the Office, Chief of Engineers, U. S. Army, in the 3rd Indorsement, dated 1 November 1968, to a request from the District Engineer, U. S. Army Engineer District, Portland. The studies were made with two models at the Division Hydraulic Laboratory, U. S. Army Engineer Division, North Pacific, during the period July 1969 to March 1975.

During the studies personnel of the Office, Chief of Engineers, North Pacific Division, and Portland District visited the Laboratory to discuss test results and correlate them with design work in progress.

The studies were conducted by Mr. T. D. Edmister, engineer in charge, under the direct supervision of Messrs. H. P. Theus, former Director of the Laboratory, A. J. Chanda, former Chief of the Hydraulics Branch, and P. M. Smith, then Chief of Structures Section and now Director. This report was prepared by Messrs. Edmister and Smith.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
miles (U. S. statute)	1.609344	kilometers
square feet	0.092903	square meters
feet per second	0.3048	meters per second
cubic feet per second	0.0283168	cubic meters per second
pounds	0.4535924	kilograms

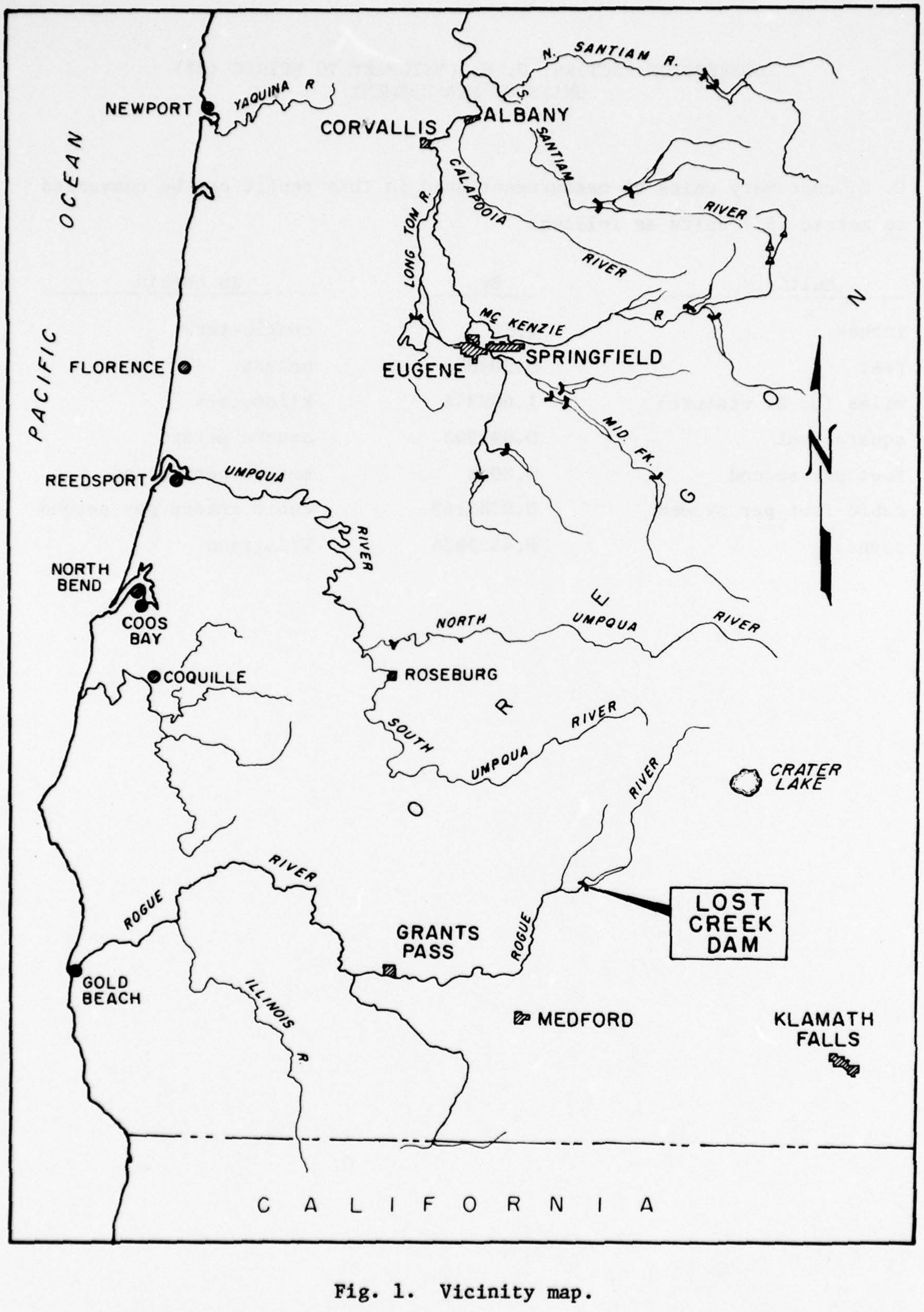

Fig. 1. Vicinity map.

OUTLET WORKS FOR LOST CREEK DAM, ROGUE RIVER, OREGON

Hydraulic Model Investigations

PART I: INTRODUCTION

The Project

1. Lost Creek project is at mile 153.6 on the Rogue River about 26.5 miles north of Medford, Oregon (fig. 1).* The project is a rockfill dam with a chute spillway, an outlet works, and a two-unit, 49,000-kw powerhouse (plate 1). The dam creates a 3,430-acre, 10-mile long reservoir with 315,000 acre-feet of usable storage with maximum pool elev 1872.** The reservoir is to be operated to provide flood control, irrigation, water supply, fish and wildlife enhancement, hydroelectric power, water quality control, and recreation. The Corps of Engineers is responsible for design, construction, and operation of the project. The Bureau of Reclamation will manage irrigation.

2. The dam is 345 ft high and 3,600 ft long at crest elev 1882. The spillway is in the left abutment and has three gated bays with crest elev 1823, a partially lined chute, and an unpaved stilling basin. The design discharge is 158,000 cfs. Estimated use of the spillway is once in 45 to 50 years. The outlet works, located near the right abutment, has an access bridge, intake tower, regulating outlet, and power penstock.

3. The intake tower is a 271-ft-high, free standing concrete structure with a 33-ft-diameter wet well that supplies the intakes of the regulating outlet and penstock. Flow to the wet well is regulated with twelve 8- by 15-ft intake ports, which are to be operated fully open or closed. Selective use of the ports will permit selective withdrawal from the reservoir for water quality, especially for control of turbidity and water

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* A table for converting U. S. customary units of measurement to metric (SI) units is presented on page iii.

** All elevations are in feet above mean sea level.

temperature to enhance the fishery downstream. The tower also has a bypass system to divert water to the penstock when the wet well is unwatered for inspection or maintenance. Flow will be bypassed through the penstock bulkhead slot, which has a 12- by 6-ft intake on the exterior of the tower at elev 1770. The bulkhead slot is oversized to pass a discharge of 2,100 cfs. An inlet to skim warm water from the reservoir surface for the fish hatchery adjacent to the project is attached to the tower.

4. The regulating outlet is a 12.5-ft-diameter tunnel that spills into a rectangular chute with a flip bucket. The tunnel is designed to pass a discharge of 10,000 cfs with 15 percent flood control storage (pool elev 1823). The maximum design capacity is 11,430 cfs (pool elev 1872). Flow is regulated by two 6.5- by 12.5-ft slide valves in the intake section of the intake tower. Head on the valves will vary from 111 to 232 ft.

5. The power penstock is a 15-ft-diameter, steel-lined conduit with a concrete intake in the intake tower. The penstock connects to two Francis turbines and has a discharge capacity of 3,000 cfs. The system is protected from debris by an intake trashrack in the wet wall.

Need for Model Study

6. The proposed regulating outlet structures were to have a combined intake tower to provide releases through the penstock and the regulating outlet. The tower was to permit temperature control of all normal releases by selective withdrawal. The model study was needed to confirm the hydraulic design of the structures and to assist in the development of required changes.

PART II: THE MODELS

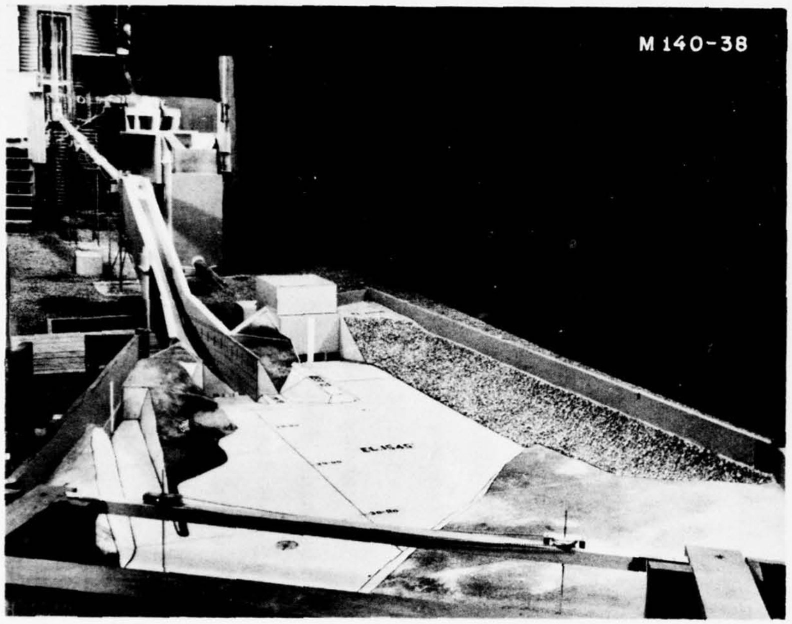
Description

7. The studies were made with two 1:40-scale models. One model reproduced the outlet works and powerhouse. The other model reproduced the intake tower bypass system.

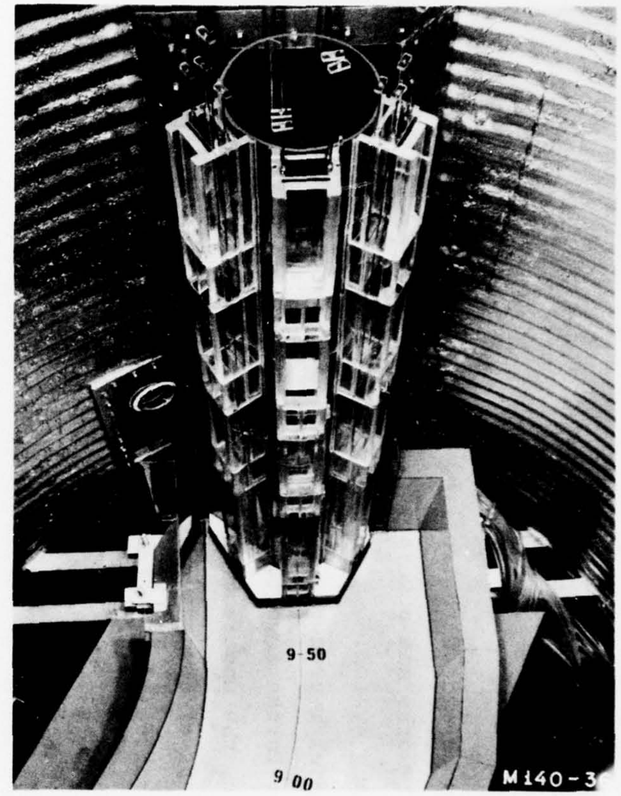
8. The outlet model reproduced a portion of the forebay and 200 ft of approach channel, the intake tower, the regulating outlet tunnel, chute and energy dissipator, the upstream portion of the penstock, the powerhouse, and about 450 ft of downstream channel. A layout of the model and details of the original design, which had a hydraulic jump stilling basin instead of a flip bucket at the end of the outlet chute, are shown in fig. 2 and on plates 2 to 9. The intake tower, tunnel, chute transition, center baffle in the stilling basin, and penstock were constructed of acrylic plastic. Topography adjacent to the intake tower, the outlet chute and stilling basin, and the powerhouse were made of waterproofed wood and plywood. The downstream channel was molded in concrete mortar between sheet metal templates and was stippled and roughened with grouted gravel to simulate rock excavation.

9. The plastic and painted wood surfaces of the model had Manning's "n" values of 0.0080 and 0.0082, respectively. When converted to prototype terms, the resulting values, 0.01479 (plastic) and 0.01516 (wood), were too rough to simulate the prototype design value of the chute, 0.010. Therefore, supplemental slopes were added to the model to create computed specific energy, depths, and velocities in the chute at the design discharge of 12,000 cfs. Roughness of the model tunnel was also excessive; however, no correction was made during the study of the original design. The tunnel flowed full at the design discharge and was not to be studied in detail. Outflow of the full tunnel had the correct specific energy. During studies of flow in the intake tower and the tunnel intake section, outflow of the tunnel was throttled to create the computed piezometric grade line in the intake section (observed at station 11+08.33).

10. The tower bypass model reproduced pertinent exterior features of the tower, the bypass bellmouth intake with trashrack and bulkhead slot,



Looking upstream



Intake tower

Fig. 2. Outlet works model, original design.

the penstock bulkhead slot and bulkhead, and a section of penstock downstream from the tower. A layout of the model and details of the structures are shown in fig. 3 and on plates 10 and 11. The model was constructed of steel pipe, sheet metal, wood, plywood, and acrylic plastic.

11. Water was supplied to the models by recirculating systems and measured by means of V-notch weirs and calibrated orifices in the supply lines. Water-surface elevations were measured with point gages and water manometers connected to piezometers in the models. Piezometers connected to 1/2-in.-diameter and 1/8-in.-diamter (quick-acting) water manometers were used to measure pressures at selected locations in each model. Velocities were measured with a miniature propeller meter. Tailwater elevations in the outlet model were controlled by an overflow gate to reproduce tailwater data furnished by the Portland District. Flow through the tower bypass system was regulated by a valve at the end of the penstock section.

Scale Relationships

12. The required similitude of the models to the prototype was obtained with the following scale relationships based on the Froude model law:

Dimension	Scale Relationship
Length	1:40
Area	1:1600
Velocity	1:6.32
Time	1:6.32
Discharge	1:10,119
Roughness	1:1.85
Weight	1:64,000

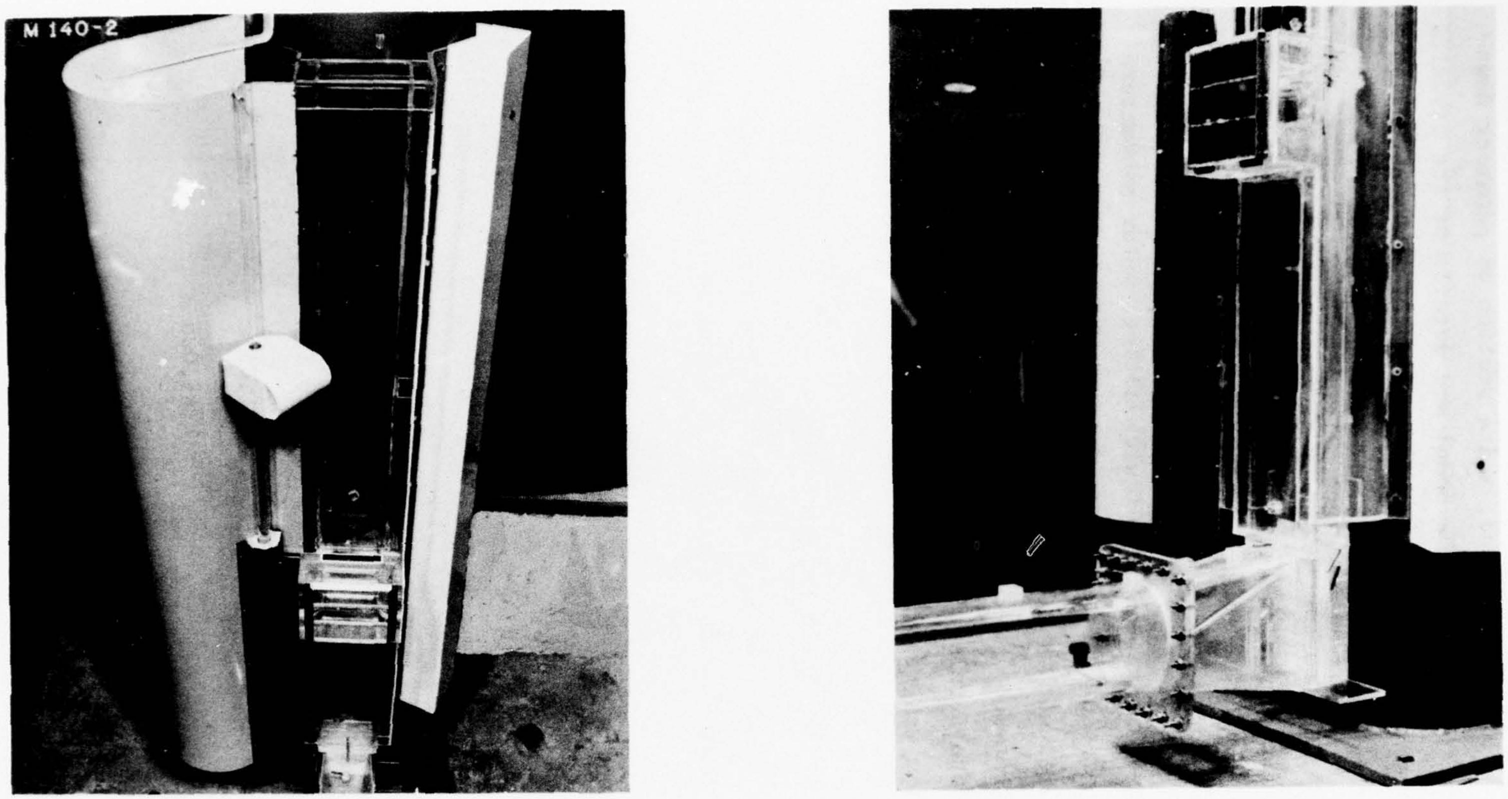


Fig. 3. Tower bypass system model.

PART III: TESTS IN OUTLET MODEL

Original Design

Design Discharge Verification

13. Design discharges of the regulating outlet were verified. With the computed pressure gradient at station 11+08.33, 10,000 cfs passed with pool elev 1822.8. The design value was elev 1823. With maximum pool elev 1872, the discharge was 11,400 cfs. The design capacity was 11,430 cfs. The chute and stilling basin design discharge of 12,000 cfs passed through the outlet with pool elev 1891. The velocity of flow into the stilling basin was slightly higher than the computed value, which indicated that the observed performance was on the conservative side for design.

Intake Tower, Penstock, and Regulating Outlet Tunnel

14. No adverse pressures were observed in the system (tables A and B). With some flow conditions small bubbles were entrained in the wet well flow and drawn into the penstock and regulating outlet. The entrainment was caused by surface turbulence and intermittent vortices within the well and vortices at the intakes. The deepest vortices extended 8 to 10 ft into the wet well before disintegrating into the highly turbulent flow. Air was entrained intermittently as bubbles, most of which rose to the surface. The model did not reproduce the vortices or air entrainment to scale but did indicate qualitatively the flow conditions that would occur in the prototype. It was concluded that vortices would not extend into the penstock or introduce large quantities of air to it but that bubbles would be entrained in the outflow with some operating conditions, which would be acceptable. As general information, the smallest intake tower discharges with which entrained air entered the penstock in the model with given pool elevations are shown on plate 12.

15. Piezometers T-5, T-6, and T-7 (plate 3) were studied as prototype piezometers to aid in measuring water-surface differentials between the forebay and the tower wet well. The differentials in table C were observed with discharges up to 4,000 cfs through the penstock and the regulating outlet. Various intakes were open in tier No. 3; intakes in tiers Nos. 1,

2, and 4 were closed. None of the three piezometers was accurate for all test conditions because all were affected by direct impact or turbulence. Only piezometers T-1 and T-2 were not affected. A piezometer at elev 1690 or elev 1765 would probably have been satisfactory; however, other locations and operating conditions were not investigated.

16. Inflow patterns to the tower intakes observed with dye in an unstratified reservoir are shown on plates 13 to 16. Flow to most of the intakes was drawn from levels slightly higher than the intakes. Closure of the three intakes in a tier had little effect on the flow to intakes beyond the adjacent tier (plates 14 and 15). No attempt was made to simulate and study flow patterns and performance of the multilevel intake structure with the stratification expected in the prototype reservoir.

17. Runoff from winter rains and melting snow may wash colloidal clay into the reservoir. The colder turbid inflow should mix with the less dense reservoir water but still plunge and form a density current along the bottom of the reservoir. That turbid water should be removed during the winter and spring, so clear cool water can be drawn from the lower levels for fishery enhancement during the low water period of late summer. A proposed method was to draw 2,500 to 3,000 cfs of the muddy water from the bottom through the bottom center port of the intake tower (intake No. 2, tier No. 4, plate 3) and discharge it through the penstock. Maximum and minimum water-surface differentials between the tower well and forebay and water surface and pressure surges within the tower and penstock are listed in table D for that method of operation. The maximum differential, 13.1 ft, occurred with a flow of 3,000 cfs. The maximum surge in the tower was 1.9 ft (minimum conservation pool elev 1751, discharge 2,500 cfs), and the maximum in the penstock was 2.7 ft (powerhouse design discharge 3,000 cfs). The surges were random. With pool elev 1751 and 1812 flow in the tower was highly turbulent with boils and small dimples at the surface. The occurrence of vortices in the prototype was indicated. As with all intakes open (paragraph 14), the turbulence disintegrated the spiral vortex flow a short distance below the surface. It was concluded that vortices would not be a problem. The tower water surface was calm with pool elev 1872 (discharge 2,500 cfs). Pressures at piezometers T-1 to T-8 were positive

for all test conditions. Flow conditions in the tower and penstock with the proposed method were considered satisfactory.

Outlet Chute Transition

18. The original transition from the circular tunnel to the rectangular chute was an expanding section with corner fillets (plate 8). Pressures along the fillets were satisfactory (table E). The minimum pressure, -3.6 ft at the upstream quarter point of the fillets, occurred with the design discharge of 12,000 cfs (photograph 1). Separate operation of the service valves had little effect on flow conditions in the transition and chute (photograph 2). Flow depths along the chute walls were similar. Depths along the left wall of the upper half of the chute are listed in table F and shown on plate 17. The maximum depths along the chute transition occurred intermittently when tunnel flow alternated between open channel and pressure flow with 5,830 cfs through fully open valves, a condition that would not occur in the prototype during normal operation. The condition occurred with a pool level below the minimum conservation pool. The 6,300-cfs discharge represented open-channel flow in a nearly full conduit with control at the service valves. That condition was satisfactory. Because of the differences in tunnel roughness and slope, these two flow conditions would occur at slightly smaller discharges in the prototype. The walls were overtopped between stations 21+42 and 22+22 by a discharge of 12,000 cfs. A surface wave with a reflection angle of approximately 10 degrees developed at each wall near the end of the chute transition. The waves converged within the chute, and no adverse conditions developed.

Outlet Stilling Basin and Tailrace

19. The original design stilling basin did not function satisfactorily with the anticipated normal tailwater (plate 18). A forced hydraulic jump was maintained in the basin with all discharges by the end sill rather than tailwater even with the relatively high apron elevation desired to reduce rock excavation. The sill functioned as a control sill and spilled high velocity flow into the tailrace. Except for occasional overtopping near

the end sill, the design wall heights were adequate. Flow conditions with the design flow of 12,000 cfs are shown in photograph 3 and on plates 19 and 20. Depths and velocities in the toe curve and stilling basin with discharges of 10,000 and 12,000 cfs are listed in table G.

20. Flow conditions in the tailrace were satisfactory. Although basin outflow with lower velocities was desirable, the high velocity flow was acceptable because the area was excavated in sound rock. A maximum bottom velocity of 16 fps occurred along the right bank just downstream from the stilling basin runout slope with the 12,000-cfs regulating outlet flow (plate 20). A reverse flow with bottom velocities of 2 to 7 fps occurred along the left bank with all regulating outlet discharges. With 3,000-cfs powerhouse flow only, velocities were 3 to 4 fps over the berm downstream from the powerhouse (plate 21).

21. Pressures were satisfactory on the end sill but not on the baffle piers (plate 9, table H). With the design discharge of 12,000 cfs, the average pressure on the baffle pier at piezometer B-4 was -23.5 ft, and the low pressure was -36.5 ft. Average model pressures corresponding to prototype pressures lower than -10 ft of water indicate possible cavitation damage to baffle piers. Although pressures lower than the vapor pressure of water, about -34 ft, have no quantitative significance, they show relative intensities of pressure in hydraulic models. With tailwater 2.8 ft above normal, the minimum average pressure was -12.5 ft, which indicated that the basin would have to be lowered 3 ft or more to have average pressures no lower than -10 ft on the proposed baffle piers. No other basin elevation or baffle design was tested because it was desired to keep rock excavation to a minimum.

Modified Designs

Plan B Chute and Plan A Flip Bucket

22. Although hydraulic conditions with the outlet chute and stilling basin could have been made acceptable with greater excavation of the sound rock, use of a stilling basin might have caused flow in the river below the dam to be supersaturated with nitrogen and unsuitable for fish. Since

prototype tests* had shown that flip buckets and shallow plunge pools fixed less nitrogen into the water than deeply submerged hydraulic jump basins and value engineering had shown an economic advantage, the energy dissipator was changed to a flip bucket with a shallow excavated apron downstream (plate 22). As tested in the model, the outlet followed the same alignment as the original design; however, the prototype outlet was rotated clockwise 1° 30' 23.4" at station 10+00 (center of intake tower). The rotation increased the distance 47.3 ft between the regulating outlet and powerhouse center lines at station 28+00. The right bank topography in the model was revised to reflect the change in outlet alignment.

23. The chute slope was corrected to simulate a prototype Manning's "n" of 0.013 to produce computed specific energy, depth, and velocities for a discharge of 12,000 cfs. In previous studies, the slope was corrected for an "n" of 0.010 to provide the maximum energy entering the stilling basin. Maximum velocities at stations 25+35 and 24+93 in the flip bucket were in good agreement with design velocities. The tailwater rating shown on plate 18 was used, but the gage location was changed to that shown on plate 22. Increased turbulence from the shallow plunge pool made the old gage unreliable. Piezometers were not installed in the fillets of the chute transition because pressures were satisfactory with the previous similar design.

24. Tests of the revised chute and flip bucket were confined to river discharges of 10,000 and 12,000 cfs. The powerhouse passed 2,300 cfs of the 10,000-cfs flow, and 7,700 cfs was released through the tunnel. The powerhouse was closed during the 12,000-cfs discharge. The plan B chute transition was not adequate with the maximum discharge. Surface waves were generated by the change from full flow in the circular tunnel to free surface flow in the downstream rectangular chute at each wall near the lower end of the transition (photograph 4), and the waves overtopped the chute walls between stations 22+90 and 24+60 (plate 23). The waves converged at approximately station 22+32 and produced large amounts of spray

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* Conducted by the Hydraulic Design Section, Portland District, Corps of Engineers. No report published.

in the downstream half of the chute (photograph 5). Other waves created as the expanding jet entered the flip bucket rose to the tops of the walls at the flip bucket exit (photograph 6).

25. Flow conditions in the tailrace are shown in photograph 7 and on plates 24 and 25. With the 12,000-cfs flow, the expanding jet spread across the riverbed and impinged on the excavated side slopes. Waves rode up the right bank to elev 1570. The maximum velocity downstream of the hydraulic jump was 33 fps near the right bank. Velocities across the topography between the powerhouse and plunge pool average 8 to 10 fps.

Plan B Chute With Wave Suppressor and Plan B Flip Bucket (Final Design)

26. Flow conditions in the chute downstream from the tunnel might have been improved by lengthening the transition and revising the chute walls, but those changes would have delayed construction of the project. Experiments with various lengths, widths, and locations of wave suppressors on the chute walls resulted in the arrangement shown on plate 26. The sloping, 4-ft-wide overhangs intercepted the waves, turned them inward, and eliminated the high rooster tail. Cross-sections of flow upstream and downstream from the suppressor are shown on plate 27. Photograph 8 shows flow conditions with the suppressor during tunnel discharges of 10,000 and 12,000 cfs. The suppressor was not required with 7,700 cfs. Waves in the chute were below the walls for all test conditions (plate 28). Average and maximum depths of flow along the left wall are listed in table I. Right wall profiles were similar.

27. Decreasing the bucket width from 36 to 32 ft (plan B flip bucket, plate 26) improved flow conditions in the tailrace. Although the nappe profile for 12,000 cfs was above the walls of the revised flip bucket (photograph 9 and plate 28), little spray was deflected outside the walls, and no increase in wall height was required. The narrower flip bucket eliminated the impingement of flow on the tailrace side slopes (photographs 10 and 11). As shown by the impact areas on plates 29 to 31, clearances between the jet and the unlined channel side slopes were adequate with all flows to 12,000 cfs.

Plan B Tunnel

28. The tunnel slope was corrected to simulate a Manning's "n" of 0.012 for a discharge of 7,650 cfs with pool elev 1840, a condition of almost full flow with an intermediate operating pool. Flow transition from open-channel to full tunnel flow was satisfactory with discharges of 7,000 and 9,000 cfs, which occurred with low and high pool levels, respectively. When the tunnel was almost full, the hydraulic jumps at the valves created waves in the flow; however, the waves did not choke off the tunnel or create any major disturbance at the exit. Full flow began at the downstream end and carried a continuous stream of heavily aerated flow along the crown until the hydraulic grade line rose above the crown at the air vents. Then, full, unaerated flow occurred. During full, aerated flow the amount of air varied and caused some variation in flow depth at the exit. Neither slug flow nor gulping occurred.

PART IV: TESTS IN TOWER BYPASS MODEL

29. The bypass was designed to pass minimum reservoir releases into the penstock through an oversized (double) bulkhead slot when the tower was not in operation. The slot was in the tower and had a bellmouth intake to the reservoir. The design discharge for the system was 2,100 cfs. Minimum design pools were elev 1826 with 2,100 cfs and elev 1789 with 1,050 cfs. Details of the model are shown in fig. 3 and on plates 10 and 11. Flows of 3,000 (maximum powerhouse discharge), 1,050, and 700 cfs were tested with the maximum project design pool elev 1872. Because the intake bulkhead (not shown) may be left in the slot or removed for storage during operation of the system, tests were made with the slot covered and open. The penstock bulkhead, which had a sloping top (plate 11) to minimize bulkhead vibration and flow losses past it, was located in the upstream position in the slot during bypass operation.

30. Pressures in the system with the intake bulkhead slot open and closed were satisfactory (tables J and K). Use of the hatchery water supply inlet, which protruded into the surface flow near the bypass intake, had no significant effect on the pressures. Flow patterns at the intakes are shown in photographs 12 and 13. Intermittent vortices formed over the intakes with minimum pool elev 1789 and a discharge of 1,050 cfs when the bulkhead was covered (photograph 13). When the intake bulkhead slot was open, only a small surface dimple formed intermittently over the slot. In the prototype a vortex might form, perhaps intermittently, and 1,050 cfs could not be passed with minimum pool elev 1789 without the possibility of some undesirable air entrainment. A small dimple also occurred with pool elev 1812 and 2,100 cfs. In the 1:40-scale model, no air was drawn into the system by either type of vortex.

31. Limits for air-free operation of the system in the model are listed in table L. All proposed operation was free of air entrainment. Vortices that did not entrain air formed over the intake or the open intake bulkhead slot with the higher pool (table M). When the discharge was 700 cfs and the intake bulkhead slot was open, air entered first through the open slot as the pool level decreased to elev 1781, 1 ft above

the slot; water entered the slot as free flow with air entrained at the surface. With a flow of 1,050 cfs, that condition occurred with pool elev 1782 (photograph 13), and air entered through the penstock bulkhead slot with pool elev 1782.5. As the pool decreased with all other conditions observed, air was first entrained by turbulence in the penstock bulkhead slot when the bypass intake throat was submerged 3 to 8 ft. When the intake bulkhead slot was open, air was entrained at a higher pool elevation with the low discharges of 700 and 1,050 cfs than when the slot was covered. That occurred because flow through the open slot affected the turbulence and direction of flow into the penstock bulkhead slot. With a discharge of 1,600 cfs and greater, the open slot affected the limiting pool elevations but not the limiting water levels in the penstock bulkhead slot. The intake was more efficient when the intake bulkhead slot was closed (bulkhead stored in slot). The model did not simulate the vortex action or air entrainment to scale; the limits of both would be at higher pool elevations in the prototype. It was concluded that the data indicated that flow conditions would be satisfactory with all the proposed discharges and pool elev 1826. However, a discharge of 1,050 cfs could not be passed satisfactorily with minimum design pool elev 1789. A discharge no greater than 700 cfs could be passed with that pool.

32. Pressures observed on the sloping top of the penstock bulkhead when the pool was just low enough to allow air to enter the system are listed in table N. All pressures were positive except those at piezometer 18 during the maximum discharge of 3,000 cfs (-2 and -4 ft with the intake bulkhead slot covered and open, respectively).

TABLE A

PRESSURES IN REGULATING OUTLET INTAKE

Piezometer Number	Powerhouse Closed			Powerhouse Discharge 3,000 CFS			
	Regulating Outlet Discharge in CFS						
	12,000	10,000	7,960	11,000	10,000	7,960	11,000
	Pool Elevation in Feet - MSL						
	1891.3	1822.8	1757.4	1860.5	1829.0	1762.8	1865.9
	All Intakes Open						Tier No. 4 Closed
	Pressure in Feet of Water						
E1	228.0	159.1	94.3	196.4	165.2	100.0	198.3
E2	213.8	150.6	91.3	184.1	152.5	101.5	173.2
E3	189.4	137.1	84.3	165.3	144.7	94.9	153.4
E4	187.5	121.0	76.0	147.6	130.2	88.2	136.3
E5	138.1	100.6	64.0	124.0	111.3	71.7	115.0
E6	124.4	91.7	56.9	111.9	101.2	61.7	107.3
E7	125.5	92.5	57.3	113.8	101.4	61.0	110.7
E8	122.4	90.3	55.2	110.9	97.7	57.9	109.9
E9	226.4	150.6	88.8	185.3	156.2	94.4	177.5
E10	209.6	148.0	89.5	181.3	154.4	95.3	171.4
E11	183.7	134.0	81.1	162.7	140.1	87.2	154.2
E12	*	*	*	*	*	*	*
E13	121.7	89.9	53.3	109.9	94.4	55.5	109.9
E14	222.3	154.0	89.2	190.5	159.0	92.8	190.0
E15	216.7	152.5	91.5	187.1	158.1	97.0	181.1
E16	190.4	137.2	83.2	167.2	144.2	95.9	149.6
E17	191.8	123.3	75.3	151.0	130.3	88.0	141.4
E18	134.6	119.5	60.0	121.1	105.5	74.2	116.5
E19	119.8	88.5	52.8	108.2	93.7	62.8	104.2
E20	123.8	91.7	54.5	112.5	97.0	63.8	111.1
E21	116.4	86.4	51.9	106.4	91.5	57.5	105.6
E22	200.3	142.7	87.6	172.7	147.9	90.2	163.9
E23	185.4	134.3	81.3	162.8	137.9	85.6	167.8
E24	156.9	114.8	68.3	138.8	116.9	71.3	137.6
E25	214.8	158.7	96.8	193.3	161.8	99.8	179.9
E26	196.6	144.3	88.8	175.4	147.9	91.5	170.9
E27	167.8	122.7	75.7	149.3	126.6	78.2	149.8
E28	155.6	113.7	70.3	138.3	117.8	73.0	140.4
E29	174.0	126.9	78.9	154.4	130.9	81.8	156.1
E30	185.2	134.8	84.1	163.3	138.8	87.2	173.7
E31	179.9	132.3	83.6	159.9	136.0	86.8	164.8
E32	180.5	131.8	84.5	159.5	136.5	88.3	164.7
E33	218.3	153.7	93.5	190.5	161.7	102.0	184.7
E34	203.0	144.2	89.7	179.7	154.1	98.7	175.1
E35	180.3	130.0	80.9	161.6	139.1	90.5	157.1
E36	153.2	111.0	67.8	137.8	119.0	74.4	126.7
E37	137.3	100.6	60.7	124.2	107.5	66.0	123.6
E38	137.9	101.5	61.3	124.8	107.5	65.3	125.5
E39	138.0	99.9	59.9	122.7	105.7	63.2	124.5
E40	223.5	154.9	90.0	192.0	160.0	93.0	193.1
E41	224.9	158.8	95.5	195.5	166.0	99.7	194.3
E42	198.8	141.7	87.2	175.3	150.2	96.2	169.5
E43	180.0	129.0	80.0	160.0	139.8	89.0	164.1
E44	150.9	110.5	67.5	137.3	119.0	76.4	133.7
E45	137.1	100.2	60.3	124.3	107.5	67.2	124.1
E46	140.6	102.8	62.2	127.0	108.5	69.5	128.4
E47	140.5	101.7	60.8	125.4	106.4	65.8	127.8
E48	196.4	142.9	85.9	175.0	147.3	88.7	178.1
E49	167.1	121.8	70.2	149.0	127.4	76.7	149.9
E50	200.6	144.3	90.3	174.4	148.8	93.6	180.3
E51	194.0	140.3	86.3	170.4	143.8	90.6	166.4

* Piezometer inoperative

NOTES: 1. Piezometer locations are shown on plate 6.

2. Service valves in regulating outlet fully open.

TABLE B

PRESSURES IN REGULATING OUTLET VALVE SECTION,

TUNNEL TRANSITION, PENSTOCK, AND INTAKE TOWER

Piezometer Number	Powerhouse Closed			Powerhouse Discharge 3,000 CFS			
	Regulating Outlet Discharge in CFS						
	12,000	10,000	7,960	11,000	10,000	7,960	11,000
	Pool Elevation in Feet - MSL						
	1891.3	1822.8	1757.4	1860.5	1829.0	1762.8	1865.9
	All Intakes Open						Tier No. 4 Closed
	Pressure in Feet of Water						
G1	139.6	101.1	59.4	123.5	105.5	62.4	124.8
G2	136.6	98.5	57.7	120.7	102.4	60.8	122.6
G3	135.7	98.7	59.7	122.1	103.9	65.2	122.8
G4	140.8	101.7	61.2	124.9	107.0	64.9	126.5
G5	143.3	105.7	64.7	128.2	109.3	65.3	128.3
G6	159.4	118.5	75.5	142.4	123.4	78.8	142.8
G7	150.6	113.0	71.6	135.6	117.6	74.5	136.3
G8	154.1	114.6	72.4	138.0	119.1	74.9	139.7
G9	150.6	112.4	71.5	135.1	116.6	73.5	135.8
G10	148.1	110.6	70.4	132.6	114.6	72.4	132.3
G11	159.8	117.6	74.5	141.6	122.8	77.1	145.8
G12	153.0	113.5	71.5	136.5	117.9	74.2	138.5
S1	131.8	99.9	61.2	121.6	103.6	62.3	118.7
S2	142.0	105.8	67.0	128.0	110.0	69.2	127.5
S3	129.9	96.3	58.2	117.2	98.8	59.3	117.2
S4	112.8	83.9	50.7	102.7	86.9	51.8	102.8
S5	119.5	90.0	56.8	108.0	93.7	58.5	108.0
S6	120.4	92.4	57.3	110.5	96.1	59.2	107.9
S7	83.8	64.4	39.0	76.9	67.5	40.2	78.1
S8	63.6	53.5	29.7	65.1	57.0	31.4	63.9
S9	86.9	65.5	37.6	80.9	69.6	39.0	79.9
S10	73.1	62.8	37.9	75.9	65.8	38.9	75.5
S11	38.3	38.1	22.3	44.3	41.5	22.8	42.5
S12	51.5	42.9	23.1	52.9	46.3	24.7	51.2
S13	55.8	47.1	29.7	55.9	49.9	30.7	54.7
S14	55.0	43.2	23.5	53.4	46.3	24.5	53.0
S15	58.9	47.9	28.7	57.9	50.8	29.8	57.0
P1	184.7	116.5	51.7	148.2	117.0	50.7	148.5
P2	186.6	118.4	53.6	150.0	118.7	52.1	148.5
P3	187.8	119.6	54.8	151.4	120.1	53.3	149.9
P4	211.1	142.9	78.1	179.2	147.1	79.1	180.1
P5	209.4	141.2	76.4	174.4	143.2	75.9	173.6
P6	208.2	140.0	75.2	172.2	141.0	74.0	171.0
P7	208.0	139.8	75.0	172.6	141.1	74.2	171.7
P8	207.8	139.6	74.8	172.3	140.8	73.7	171.5
P9	205.7	137.5	72.7	167.7	136.6	69.6	167.4
P10	205.5	137.3	72.5	168.0	136.5	72.5	167.6
P11	205.5	137.3	72.5	167.5	136.2	72.3	167.6
P12	198.6	130.4	65.6	159.6	128.5	60.9	159.8
P13	198.6	130.4	65.6	160.2	128.7	61.5	160.4
P14	208.0	139.8	75.0	168.0	136.8	72.0	168.3
P15	209.9	141.7	76.9	168.6	137.4	69.7	169.0
T1	248.8	179.6	114.0	216.8	184.6	106.5	219.6
T2	234.4	165.5	99.9	202.5	170.4	92.7	205.0
T3	160.8	93.0	29.0	127.0	96.3	21.0	123.5
T4	103.7	35.0	-	71.1	39.9	-	72.9

\- Piezometer above water surface

NOTES: 1. Piezometer locations are shown on plates 3, 4, 6, and 7.

2. Service valves in regulating outlet fully open.

TABLE C

WATER-SURFACE DIFFERENTIALS BETWEEN FOREBAY AND TOWER WET WELL

Tier No. 3 in Operation

Piezometer Number	Intakes Open				
	1		1, 2		1, 2, 3
	Discharge in CFS				
	1,000	2,000	2,000	4,000	3,000
	Water-Surface Differential in Feet				
T-1	1.5	5.6	1.5	6.4	1.5
T-2	1.5	5.6	1.5	6.4	1.5
T-3	1.5	5.8	1.5	6.9	1.8
T-4	1.5	5.5	1.5	6.2	1.5
T-5	1.8	5.9	1.8	6.4	1.8
T-6	1.7	5.2	1.8	7.0	1.7
T-7	1.5	3.9	1.0	2.3	1.5

NOTES:
1. Forebay varied between elevation 1870 and 1874.
2. Up to 3,000 cfs passed through the penstock with the remainder through the regulating outlet.
3. Intake and piezometer locations shown on plate 3.

TABLE D

WATER-SURFACE DIFFERENTIALS BETWEEN FOREBAY AND TOWER WET WELL
AND SURGE WITHIN TOWER AND PENSTOCK

Intake No. 2, Tier No. 4 in Operation

Pool Elevation in Feet - MSL					
1751		1812		1872	
Discharge in CFS					
2500		3000		2500	
Water-Surface Differential in Feet					
Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
9.9	8.0	13.1	11.4	8.6	7.8
Maximum Surge in Feet					
Tower	Penstock	Tower	Penstock	Tower	Penstock
1.9	2.5	1.7	2.7	0.8	1.2

NOTES: 1. All flow passed through the penstock.

2. Surge within penstock measured at piezometer P-15.

3. Tower and penstock details shown on plates 3 and 4.

TABLE E

PRESSURES

Regulating Outlet Chute Transition

Original Design

Piezometer Number	Discharge in CFS	
	10,000	12,000
	Pressure in Feet of Water	
C-1	-1.6	-3.6
C-2	2.2	1.4
C-3	3.6	1.9

NOTE: Piezometer locations shown on plate 8.

TABLE F

MAXIMUM DEPTHS ALONG LEFT CHUTE WALL

Original Design

Station	Discharge in CFS			
	5,830	6,300	8,000	12,000
	Maximum Water Depth in Feet			
20+55	11.5	9.0	8.0	6.3
20+60	13.0	9.0	8.0	8.0
20+70	15.4	8.7	8.0	8.1
20+80	16.0	7.9	8.0	8.5
20+90	15.2	6.8	8.5	8.5
21+00	13.0	6.4	9.8	8.5
21+10	10.0	6.8	10.0	8.5
21+20	8.5	7.0	10.3	8.5
21+30		8.2	10.5	10.0
21+40		8.0	10.0	12.0
21+50		7.5	9.5	14.0
21+60			9.0	15.0
21+70		6.3	8.5	15.6
21+80		6.7	8.0	15.1
21+90		6.3	7.5	14.7
22+00		6.1	7.5	13.8
22+10		6.0	7.3	13.0
22+20		6.0	7.4	12.5
22+30		5.8	7.3	11.5
22+40				10.0
22+50		5.6	7.4	9.5
22+60				9.0
22+70		5.0	7.5	9.0

NOTES: 1. Chute details shown on plates 2 and 8.

2. Water-surface profiles shown on plate 17.

TABLE G

ENTRANCE VELOCITIES

Regulating Outlet Stilling Basin

Original Design

Station	Nappe Depth in Feet	Velocity in FPS
	Discharge 10,000 CFS	
24+25.49	4.1	121
24+95 **	2.2	124
25+50.47	2.0	100
	*Discharge 12,000 CFS	
24+25.49	4.8	124
25+00 **	2.5	129
25+50.47	2.0	120

* Stilling basin design discharge
** Toe of hydraulic jump

NOTES: 1. Stilling basin details shown on plate 9.

2. Average velocities measured normal to toe curve radius.

TABLE H

PRESSURES ON BAFFLES AND END SILL

Regulating Outlet Stilling Basin
Original Design

Piezometer Number	Discharge in CFS									
	10,000		12,000							
	Tailwater Elevation in Feet - MSL									
	*1556.9		*1558.2		1559.0		1559.5	1560.0		1561.0
	Pressure in Feet of Water									
	Low	Average	Low	Average	Low	Average	Average	Low	Average	Average
	Baffles									
B-1	-4.5	4.8	-18.5	-10.0	-17.5	-9.5	-7.0	-15.5	-5.5	-4.5
B-2	-13.0	-2.5	-32.0	-20.0	-28.5	-18.5	-18.0	-24.0	-14.5	-11.0
B-3	-9.0	2.5	-26.0	-15.2	-27.0	-15.0	-13.5	-17.0	-9.0	-6.0
B-4	-14.5	1.5	-36.5	-23.5	-33.5	-21.5	-20.5	-27.5	-16.0	-12.5
	End Sill									
B-5		32.0		36.0		36.0			36.5	
B-6		23.0		23.0		24.0			25.0	

*Normal Tailwater

NOTES: 1. Low pressures measured with quick-acting, 1/8-in.-diam water manometers.

2. Average pressures measured with 1/2-in.-diam water manometers.

3. Piezometer locations shown on plate 9.

TABLE I

DEPTHS ALONG LEFT CHUTE WALL

Plan B Outlet With Wave Suppressor
and Plan B Flip Bucket

Station	Discharge in CFS			
	10,000		12,000	
	Water Depth in Feet			
	Average	Maximum	Average	Maximum
20+35	7.3	7.3		8.6
20+40	7.5	7.5		
20+60	5.5	5.5		5.6
20+80	5.9	6.8		5.0
21+00	7.7	9.7	7.3	8.2
21+20	10.5	11.3	9.5	10.7
21+40	10.8	11.8	12.3	13.5
21+64.3	11.1	12.3	15.5	16.7
21+81	9.0	9.0		9.0
22+00	6.4	7.4	6.9	7.2
22+20	7.0	7.4	8.2	9.1
22+40	7.4	8.1	9.3	10.4
22+60	7.5	8.3	9.7	10.3
22+80	7.0	8.4	8.7	10.0
23+00	7.7	8.5	8.3	9.4
23+20	7.5	8.4	7.9	8.6
23+40	7.1	8.6	7.4	8.2
23+60	7.6	8.8	7.4	8.3
23+80	6.9	8.1	7.1	8.4
24+00	7.3	8.6	7.1	7.9
24+20	6.7	7.9	6.8	8.3
24+40	6.9	8.1	7.2	8.3
24+60	6.8	7.7	8.1	9.0
24+80	7.5	8.3	7.1	8.6
25+00			4.1	8.2
25+10	7.4	8.3	7.8	8.8
25+20	8.8	10.0	10.0	11.8
25+30	7.3	8.3	10.0	11.1
25+35	6.8	7.6	8.2	9.2

NOTES: 1. Chute, wave suppressor, and flip bucket shown on plate 26.

2. Depth is vertical distance above invert.

TABLE J

PRESSURES

Intake Bellmouth and Penstock Bulkhead Slot

Tower Bypass System

Piezometer Number	Pool Elevation in Feet - MSL															
	1872				1789		1812				1826		1872			
	Discharge in CFS															
	700		1,050				2,100								3,000	
	Intake Bulkhead Slot															
	Covered	Open	Covered	Open	Covered	Open	Covered	Open	*Covered	*Open	Covered	Open	Covered	Open	Covered	Open
	Pressure in Feet of Water															
1	95.1	95.1	95.2	95.1	12.1	12.1	34.7	35.0	34.7	35.0	48.8	49.0	94.9	95.0	94.1	94.6
2	96.4	96.3	96.4	96.3	13.3	13.3	35.5	36.2	35.5	36.2	49.4	50.2	96.1	96.2	94.6	95.5
3	96.9	97.0	96.1	96.6	13.1	13.7	33.0	34.5	32.9	34.8	46.6	48.9	92.8	95.0	88.0	91.9
4	97.4	97.9	96.4	97.3	13.3	14.2	30.0	33.0	30.1	33.2	43.2	47.3	89.4	93.3	81.0	87.9
5	97.3	97.8	95.6	96.9	12.3	13.6	26.6	31.1	26.4	31.4	40.1	45.4	86.3	91.6	73.1	84.3
6	97.7	98.3	96.0	97.4	12.5	14.0	25.7	30.9	25.4	31.1	39.0	45.1	85.1	91.8	70.2	83.0
7	97.5	98.2	95.6	97.2	12.4	13.9	25.6	31.0	25.3	31.3	38.9	45.3	85.0	91.8	70.5	83.9
8	97.8	96.3	96.7	93.8	13.2	10.8	30.7	14.9	30.3	15.8	46.8	30.2	92.3	76.5	79.8	52.1
9	95.6	94.8	93.9	92.7	10.3	8.5	24.4	16.9	24.0	17.7	38.1	31.2	83.9	77.7	70.2	58.1
10	80.7	79.9	79.0	77.9	0.1	1.9	10.0	2.7	9.6	3.3	23.8	17.0	69.5	63.4	56.5	44.9
11	101.8	101.4	97.6	98.0	13.5	13.2	16.8	13.0	16.2	14.0	31.0	28.0	76.0	74.4	45.5	42.6
12	103.0	102.1	98.5	98.2	14.8	13.1	16.8	9.1	15.8	9.9	31.0	24.3	75.9	70.6	45.1	35.5
13	103.8	102.9	99.0	98.9	15.4	13.6	16.4	8.6	15.2	9.7	30.5	24.0	75.4	70.2	43.0	33.0
14	162.2	161.7	159.0	159.2	75.7	74.7	83.2	77.9	82.3	78.1	97.0	93.9	142.4	138.7	118.7	111.0

* Hatchery water supply inlet above water surface

NOTE: Details of tower bypass system and piezometer locations shown on plates 10 and 11.

TABLE K

PRESSURES

Penstock Bulkhead and Roof

Tower Bypass System

Piezometer Number	Pool Elevation in Feet - MSL															
	1872				1789		1812				1826		1872			
	Discharge in CFS															
	700		1,050				2,100								3,000	
	Intake Bulkhead Slot															
	Covered	Open	Covered	Open	Covered	Open	Covered	Open	*Covered	*Open	Covered	Open	Covered	Open	Covered	Open
	Pressure in Feet of Water															
	Penstock Bulkhead															
15	166.7	166.2	163.7	164.0	80.6	79.7	90.0	85.7	89.2	85.7	103.8	100.9	149.3	146.1	129.4	122.0
16	167.0	166.7	163.7	164.0	80.5	79.6	86.7	81.8	86.0	82.2	101.5	97.9	146.3	142.7	121.1	114.4
17	167.7	167.0	163.3	163.9	79.8	78.9	82.2	76.2	80.8	76.7	95.9	92.8	141.4	137.1	109.9	102.5
18	166.1	165.6	157.3	159.4	73.4	72.6	53.5	47.1	51.0	47.3	67.4	65.1	111.6	109.2	53.4	48.1
19	172.1	171.8	167.7	168.7	83.7	82.0	81.7	72.8	77.2	73.2	92.7	89.3	137.8	134.5	95.5	89.5
20	178.4	177.9	173.5	174.8	89.9	89.7	89.0	84.0	89.0	86.3	103.4	102.8	149.0	145.5	116.9	107.5
21	183.8	183.0	178.3	179.8	94.7	94.9	95.0	89.5	95.0	93.5	107.2	108.0	156.0	151.0	126.8	116.0
	Penstock Roof															
22	166.4	166.3	159.8	157.9	76.5	76.0	68.5	65.0	66.8	63.2	83.5	79.8	126.5	124.8	80.0	74.3
23	167.6	167.0	160.9	162.6	77.2	76.6	68.3	64.7	67.0	63.5	82.5	79.8	126.9	123.5	79.6	74.0
24	168.5	168.4	162.1	164.4	79.4	78.5	72.9	70.5	70.2	67.5	91.2	84.5	131.2	127.7	86.6	80.2
25	169.9	169.3	163.3	165.7	80.4	79.7	75.3	71.6	74.3	70.8	94.0	86.9	133.8	130.4	92.5	87.3
26	170.2	169.4	164.2	166.0	80.7	80.3	76.8	72.3	75.8	72.6	100.9	88.1	135.2	131.7	97.5	90.6
27	170.3	169.6	164.3	166.2	80.8	80.4	76.9	73.0	76.0	72.8	101.0	88.7	135.5	132.2	98.5	91.0
28	170.4	169.5	164.3	166.2	80.9	80.5	77.0	73.2	76.1	73.0	101.1	89.0	135.7	132.2	98.8	91.1

* Hatchery water supply inlet above water surface

NOTE: Details of tower bypass system and piezometer locations shown on plates 10 and 11.

TABLE L

MINIMUM WATER-SURFACE ELEVATIONS
WITHOUT AIR ENTRAINMENT

Tower Bypass System

Discharge in CFS	Intake Bulkhead Slot			
	Covered		Open	
	Water-Surface Elevation in Feet-MSL			
	Pool	Penstock Bulkhead Slot	Pool	Penstock Bulkhead Slot
700	1776	1775	1782	1780
1,050	1778	1775	1783	1778
1,600	1785	1775	1789	1775
2,100	1796	1778	1803	1778
3,000	1810	1779	1823	1779

NOTES: 1. Air first entrained in penstock bulkhead slot except when first drawn through open intake bulkhead slot with discharge of 700 cfs.

2. Details of tower bypass system shown on plates 10 and 11.

TABLE M

VORTEX AND AIR ENTRAINMENT OBSERVATIONS

Tower Bypass System

Discharge in CFS	Maximum Pool Elev in Feet- MSL for Vortex Formation	Maximum Vortex Diameter in Feet	Description
	Intake Bulkhead Slot Covered		
700	1785	0.8	Intermittent vortex over intake, pool elev 1785. No vortex below pool elev 1781. Air entered system through intake, pool elev 1774.
1,050	1791	2.5	Dimple over intake, pool elev 1793. Intermittent vortex, pool elev 1791 to 1782. Air entrained into system in penstock bulkhead slot, pool elev 1777.
1,600	1803	3.3	Dimple over intake, pool elev 1805. Intermittent vortex, pool elev 1803. Steady vortex, pool elev 1794. Air entrained into system in penstock bulkhead slot, pool elev 1784.
2,100	1803	4.2	Dimple over intake, pool elev 1805. Intermittent vortex, pool elev 1803. Steady vortex, pool elev 1796. Air entrained into system in penstock bulkhead slot, pool elev 1795.
3,000	1804	3.3	Dimple over intake, pool elev 1805. Steady vortex, pool elev 1804. Intermittent vortex, pool elev 1802. Lower pools not observed. Air entrained into system in penstock bulkhead slot, pool elev 1809.
	Intake Bulkhead Slot Open		
700	1784	1.7	Intermittent vortex over intake bulkhead slot, pool elev 1784. Steady vortex, pool elev 1783.5. Air entered system through intake bulkhead slot, pool elev 1781.
1,050	1784	1.7	Intermittent dimple over intake bulkhead slot, pool elev 1789. Air entrained into system in penstock bulkhead slot, pool elev 1782.5. Intermittent vortex and air entered system through intake bulkhead slot pool elev 1782.
1,600	1805	2.5	Intermittent vortex over intake bulkhead slot, pool elev 1805. Air entrained into system in penstock bulkhead slot, pool elev 1788.
2,100	1806	1.5	Dimple over intake bulkhead slot, pool elev 1808. Intermittent vortex, pool elev 1806. Steady vortex, pool elev 1801. No vortex, pool elev 1799. Steady vortex, pool elev 1794. Air entrained into system in penstock bulkhead slot, pool elev 1802.
3,000	1821	-	Small vortex over intake bulkhead slot, pool elev 1821. Air entrained into system in penstock bulkhead slot, pool elev 1822.

NOTES: 1. Vortex defined as swirling surface depression with distinct spiraling filament beneath it. Dimple defined as swirling surface depression without distinct filament beneath it.

2. Details of tower bypass system shown on plates 10 and 11.

TABLE N

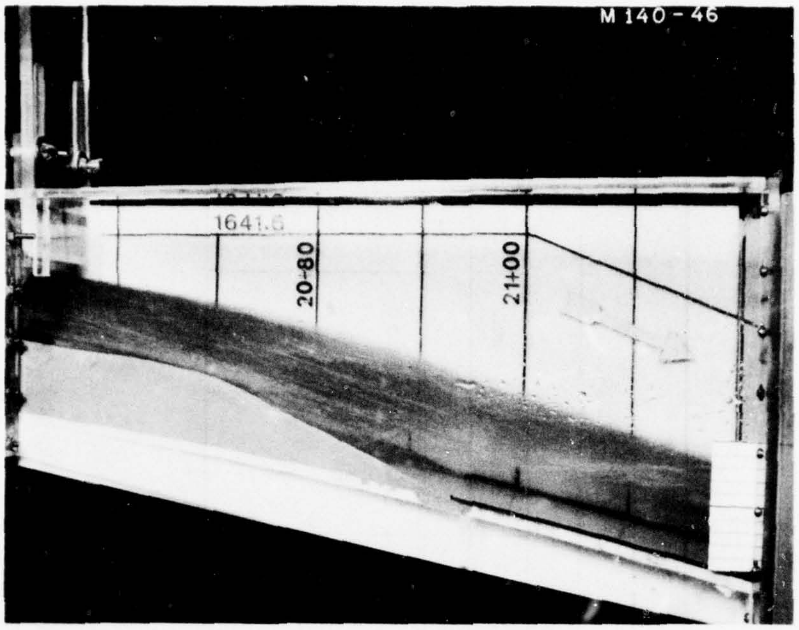
PRESSURES ON SLOPING TOP OF PENSTOCK BULKHEAD
WITH AIR ENTRAINMENT

Tower Bypass System

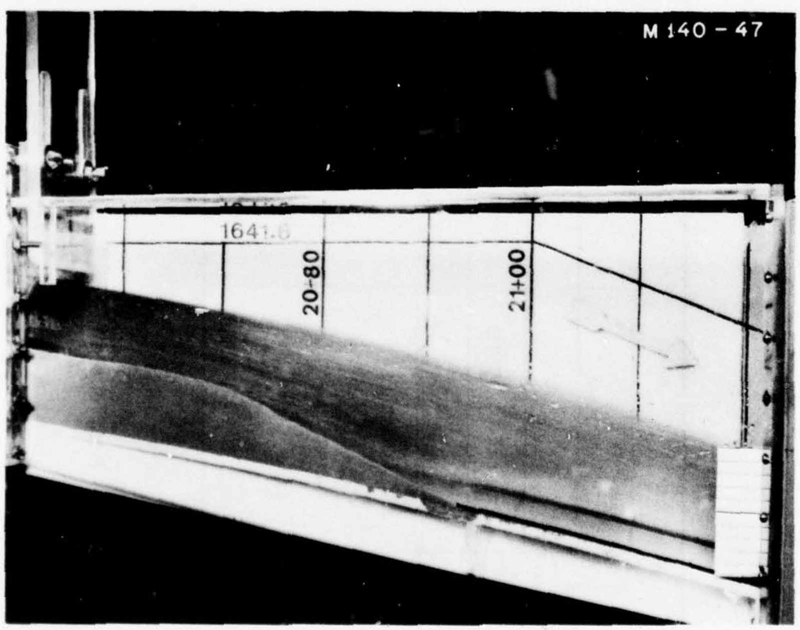
Piezometer Number	Discharge in CFS									
	700		1,050		1,600		2,100		3,000	
	Intake Bulkhead Slot									
	Covered	Open	Covered	Open	Covered	Open	Covered	Open	Covered	Open
	Pressure in Feet of Water									
15	63	75	67	73	67	68	67	68	63	67
16	63	76	66	74	65	67	64	64	57	60
17	64	76	67	73	63	65	60	60	46	49
18	63	74	59	68	50	52	34	34	-2	-4

NOTES: 1. Pool elevations 1 to 3 ft below minimum pools listed in table L.

2. Details of tower bypass system and piezometer locations shown on plates 10 and 11.

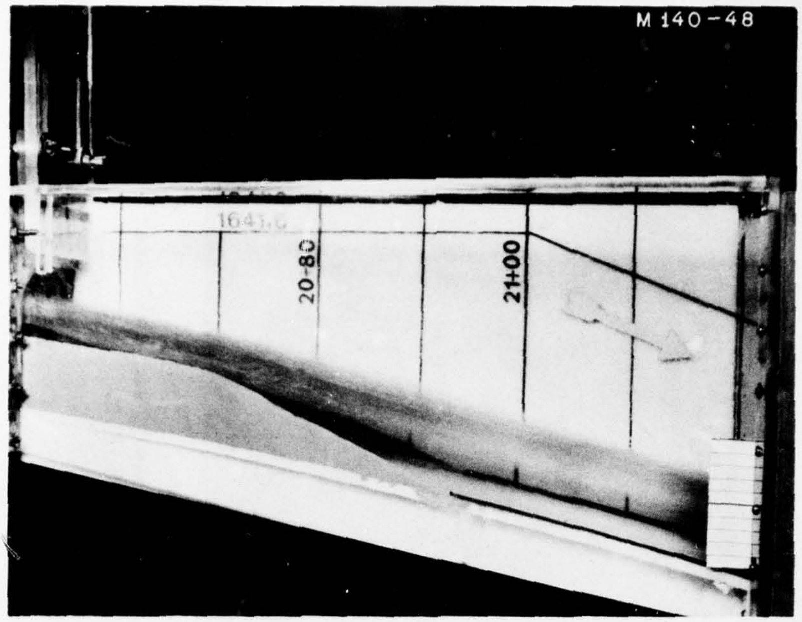


Discharge 10,000 cfs

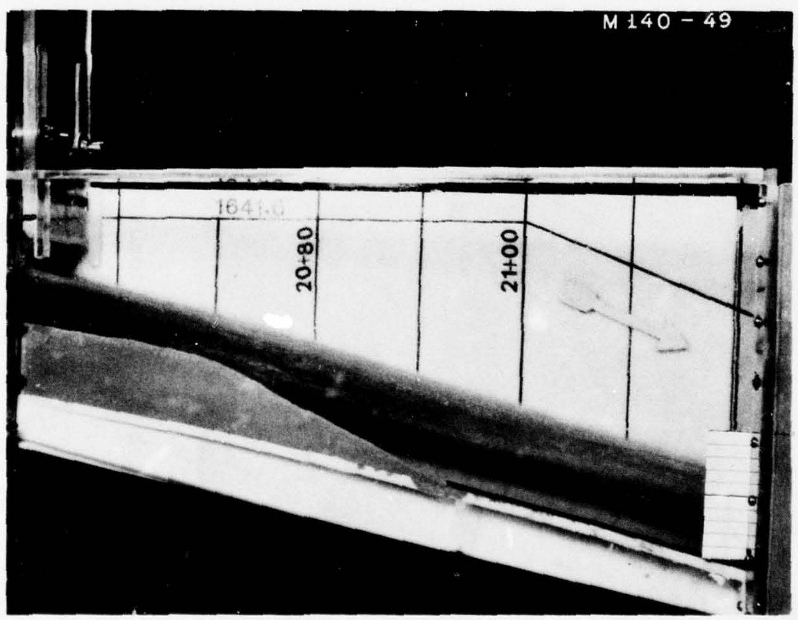


Discharge 12,000 cfs

Photograph 1. Flow profiles in original design chute transition.

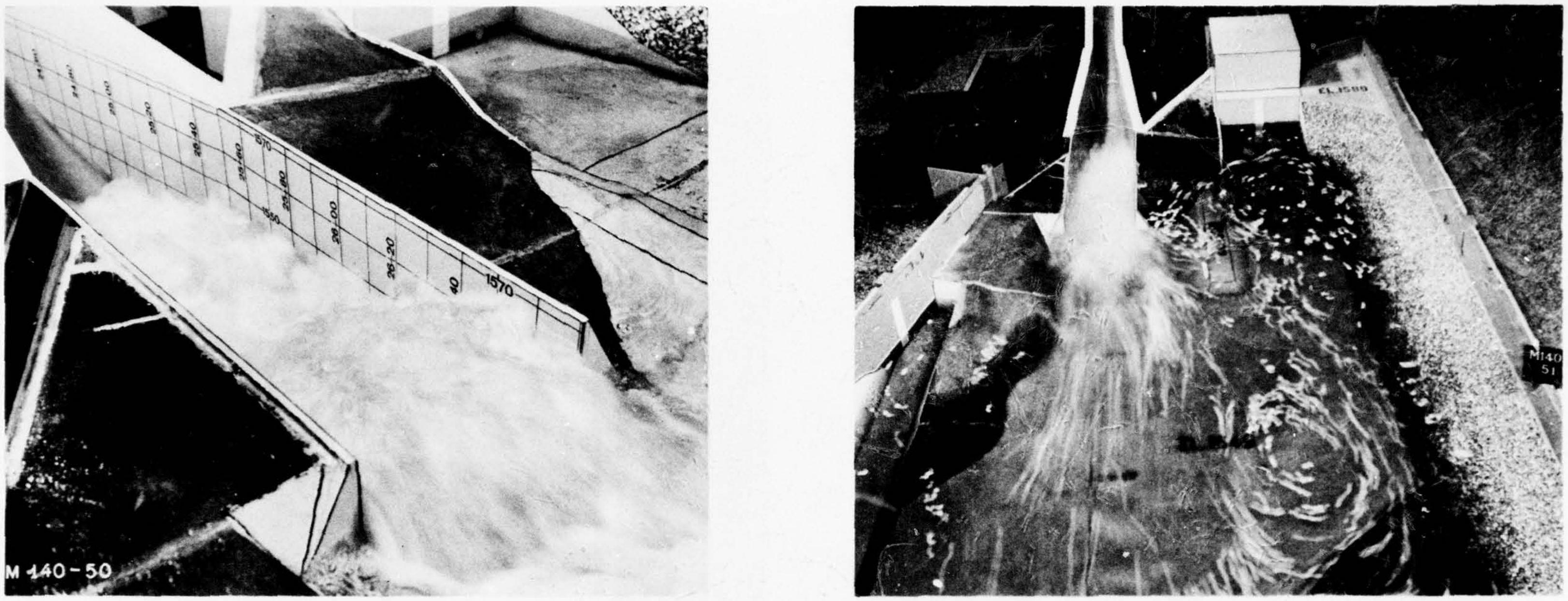


Left valve open

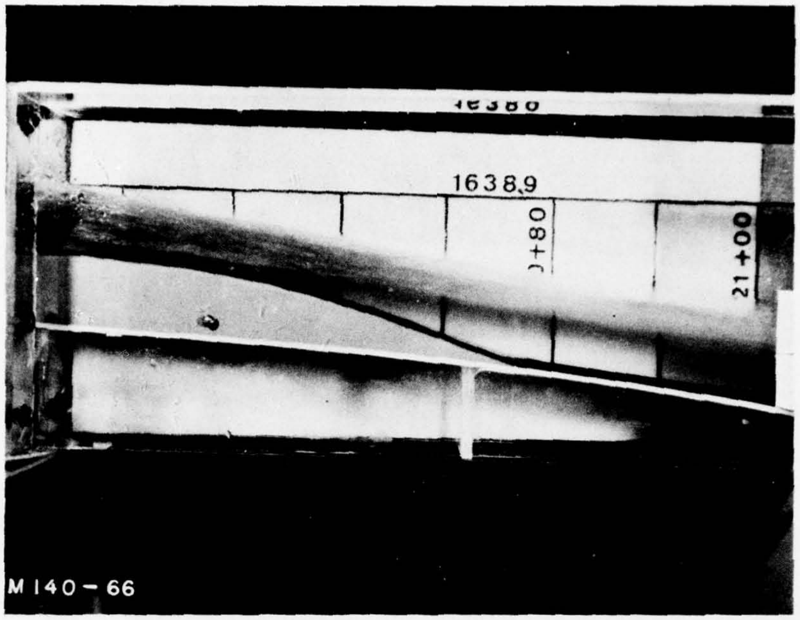


Right valve open

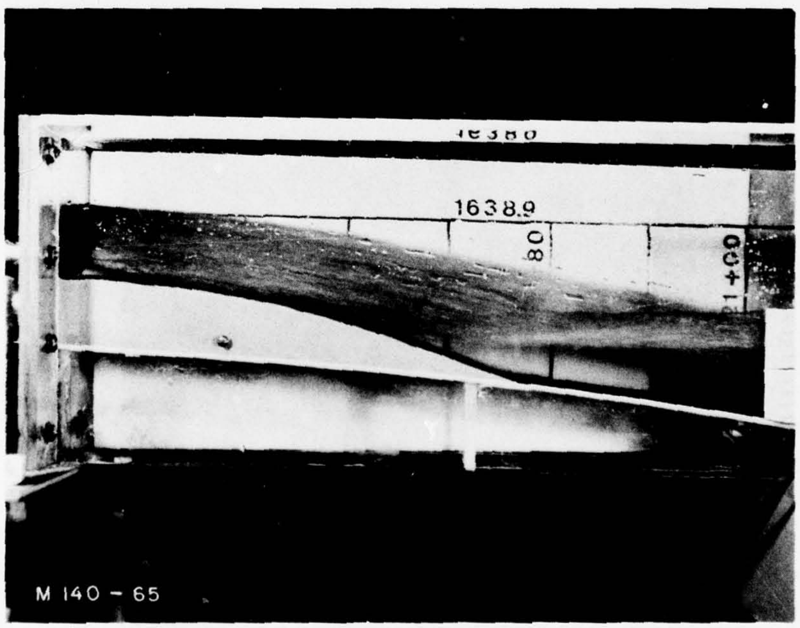
Photograph 2. Flow profiles in original design chute transition; one service valve operating, discharge 7,500 cfs.



Photograph 3. Flow conditions in original design stilling basin and tailrace; outlet discharge 12,000 cfs, tailwater elev 1558.2.

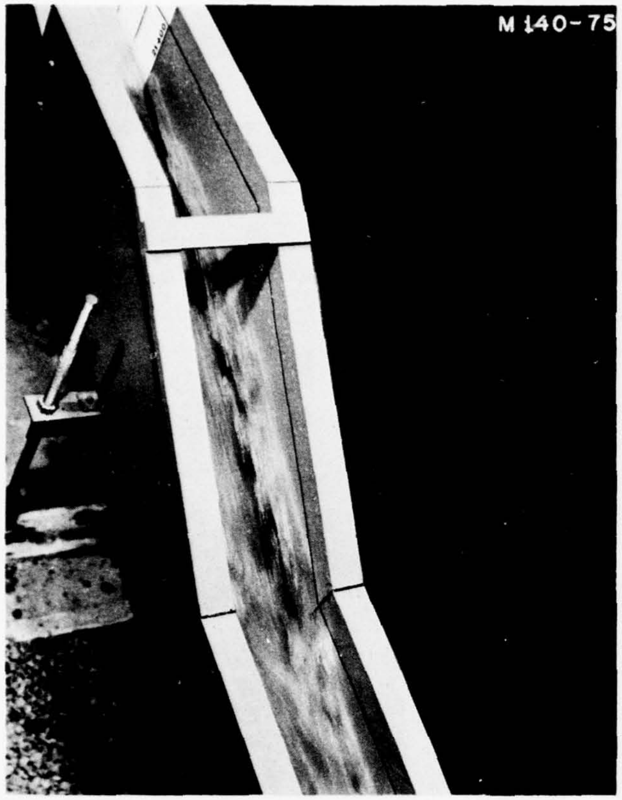


Discharge 7,700 cfs

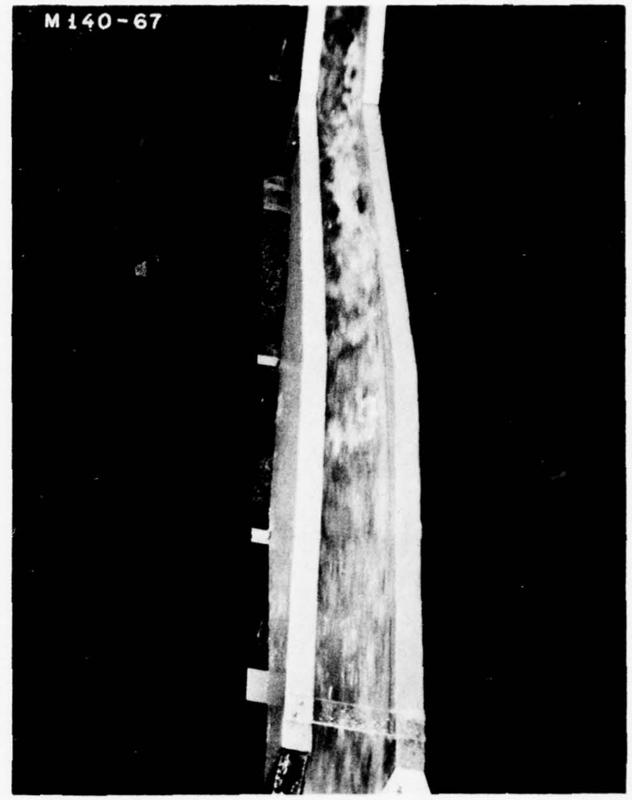


Discharge 12,000 cfs

Photograph 4. Flow conditions in plan B chute transition; both service valves fully open.

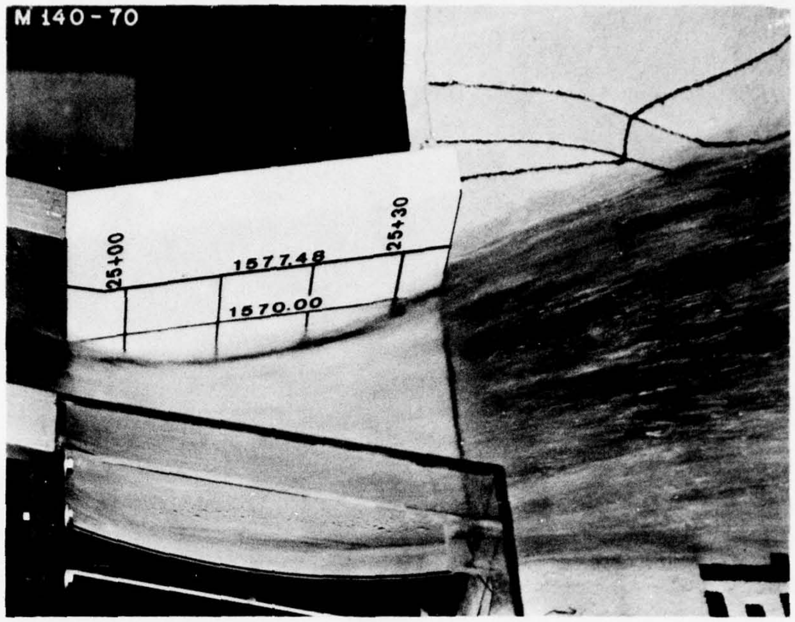


Upstream end

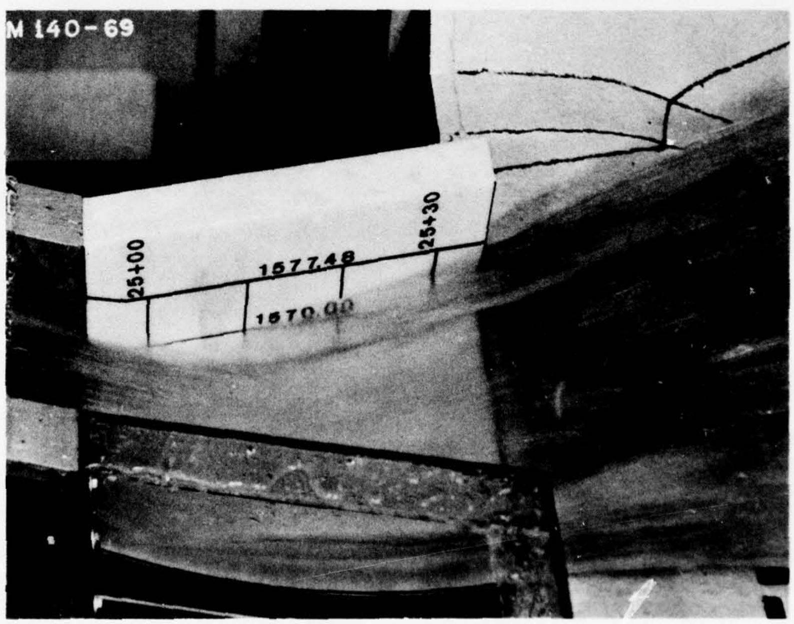


Downstream end

Photograph 5. Flow conditions in plan B chute; discharge 12,000 cfs.

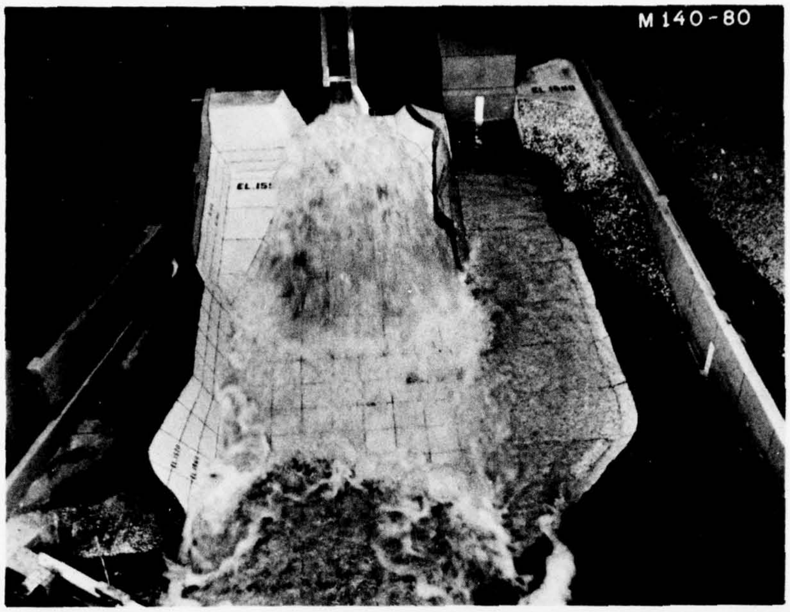


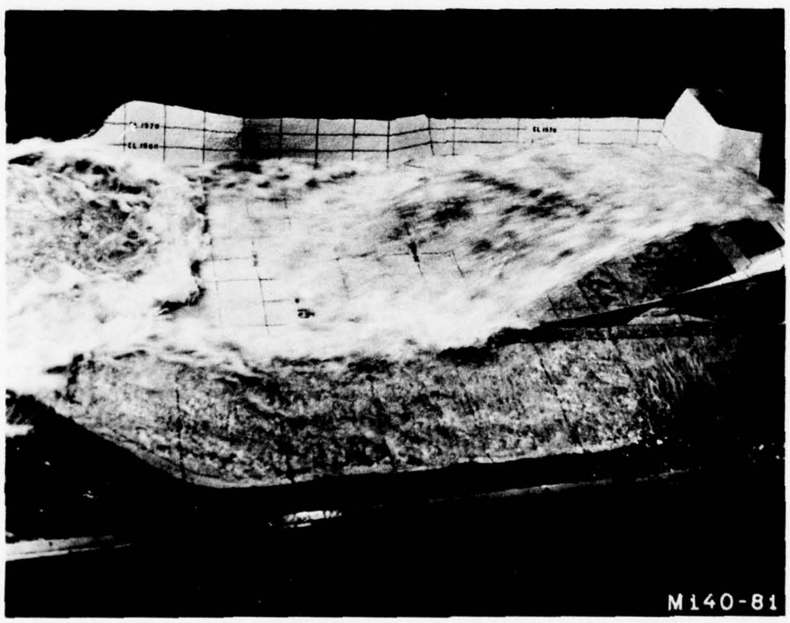
Discharge 7,700 cfs



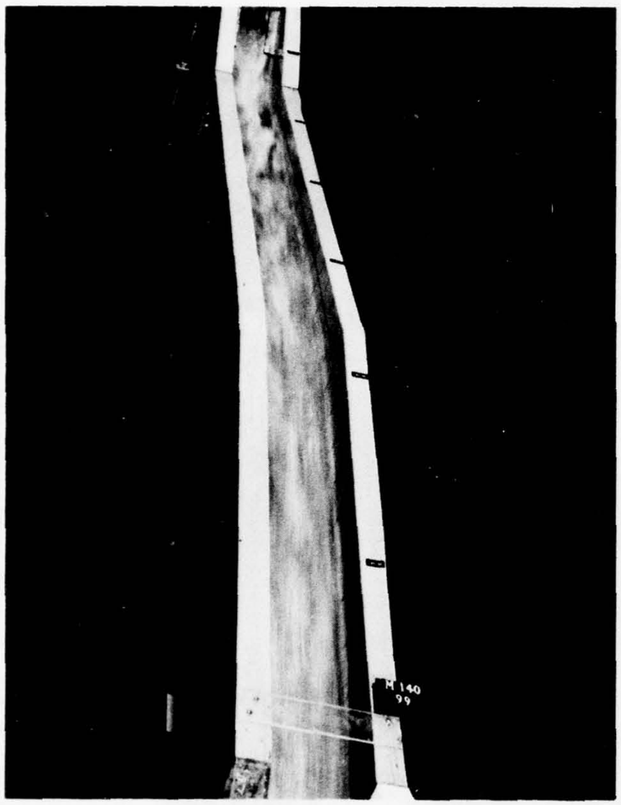
Discharge 12,000 cfs

Photograph 6. Flow conditions in plan A flip bucket.

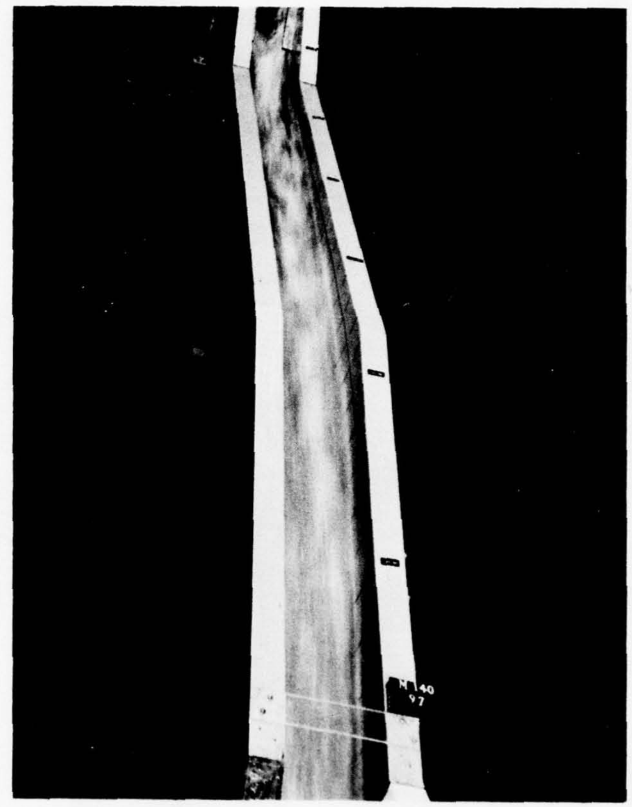




Photograph 7. Flow conditions downstream from plan A flip bucket; river and outlet discharge 12,000 cfs, tailwater elev 1558.2.

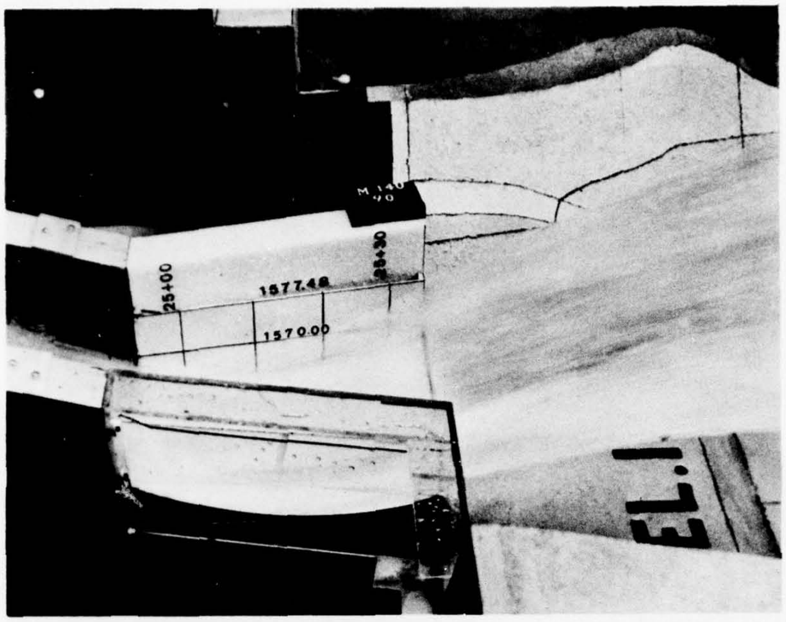


Discharge 10,000 cfs

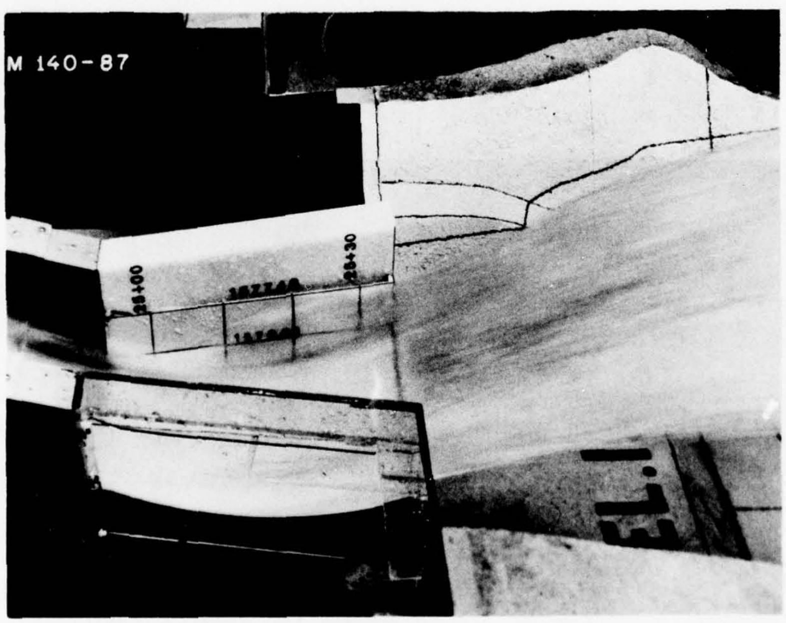


Discharge 12,000 cfs

Photograph 8. Flow conditions in plan B chute with suppressor (final design).

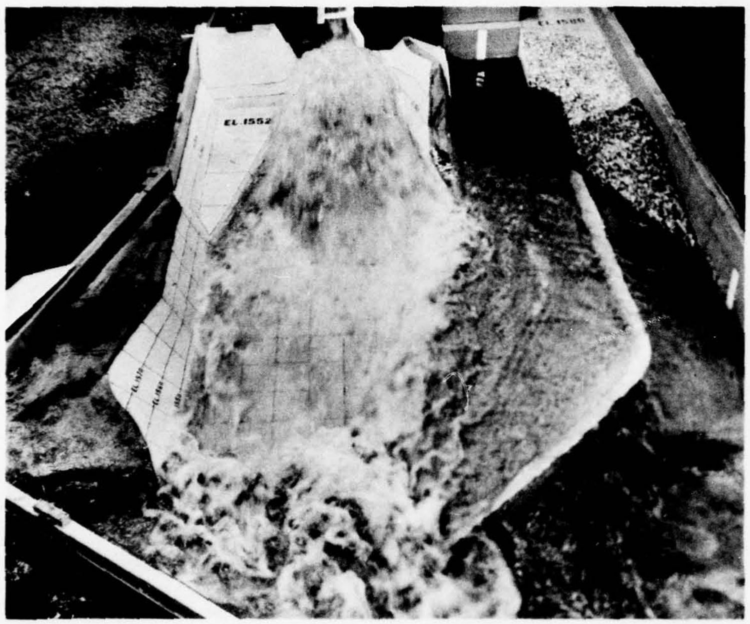


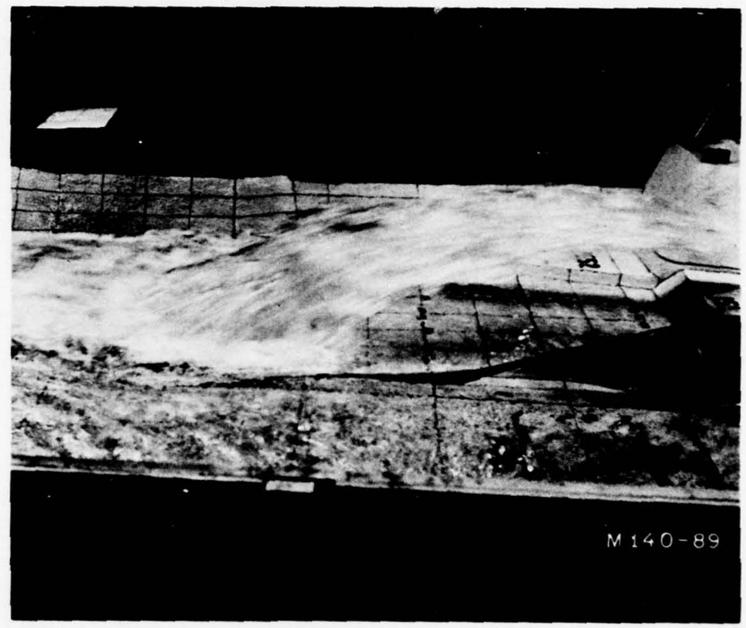
Discharge 10,000 cfs



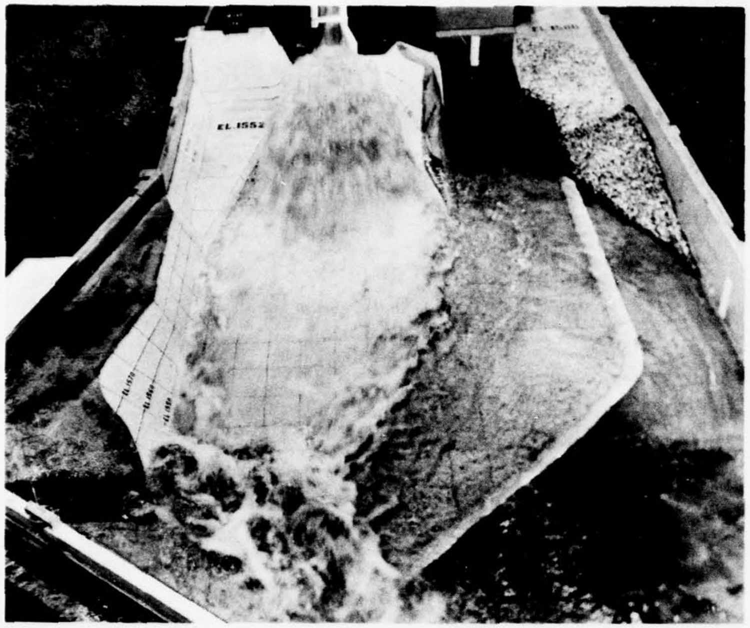
Discharge 12,000 cfs

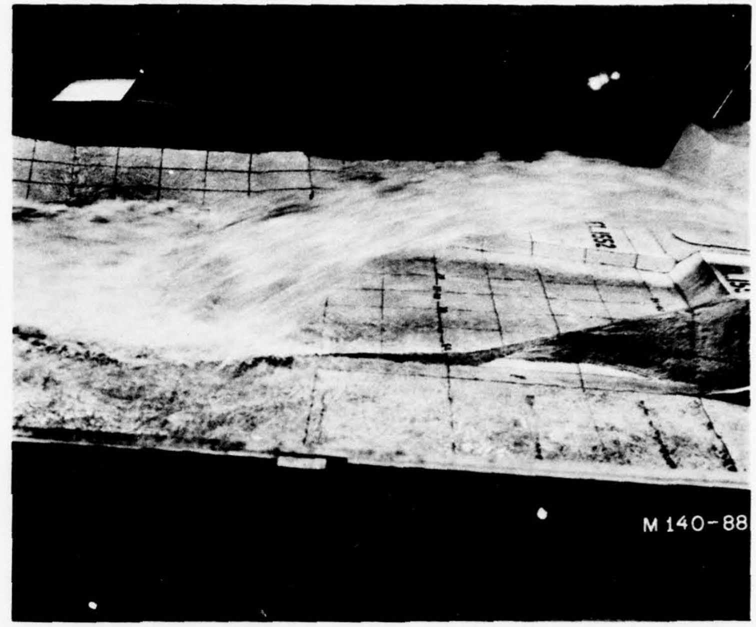
Photograph 9. Flow conditions in plan B flip bucket connected to plan B chute with suppressor.



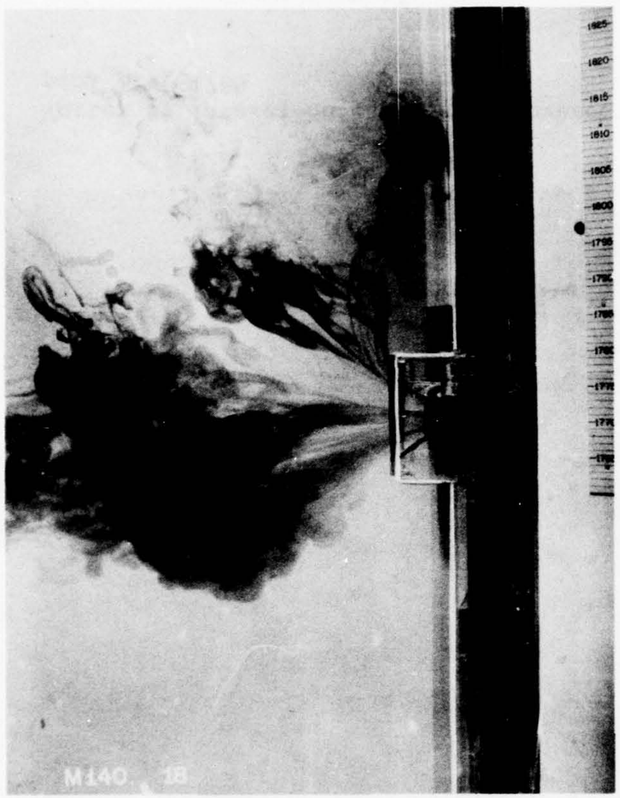


Photograph 10. Flow conditions downstream from plan B flip bucket (final design); river and outlet discharge 10,000 cfs, tailwater elev 1556.9.

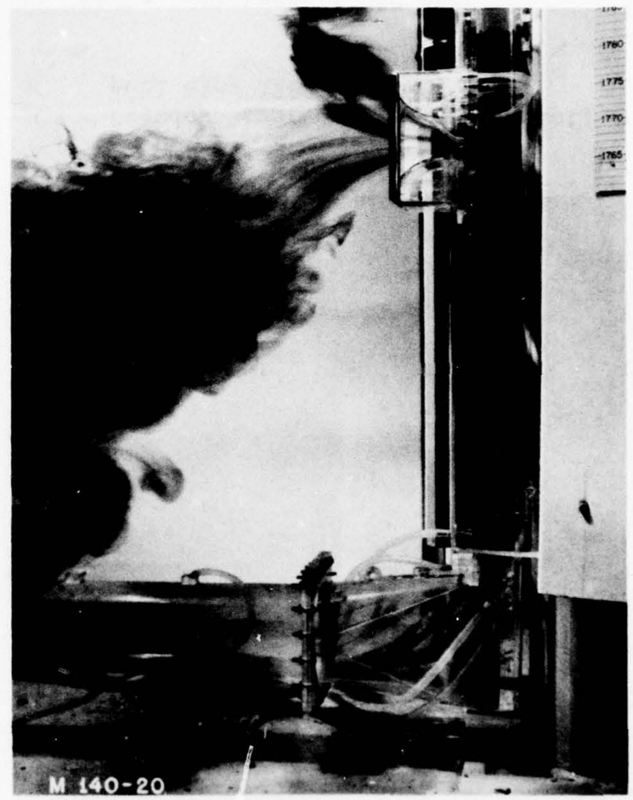




Photograph 11. Flow conditions downstream from plan B flip bucket (final design); river and outlet discharge 12,000 cfs, tailwater elev 1558.2.

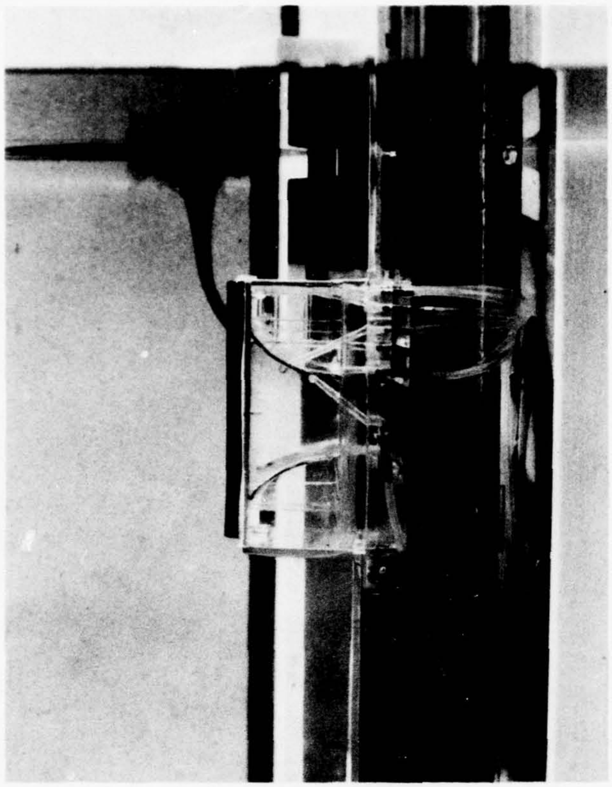


Discharge 2,100 cfs, pool elev 1872

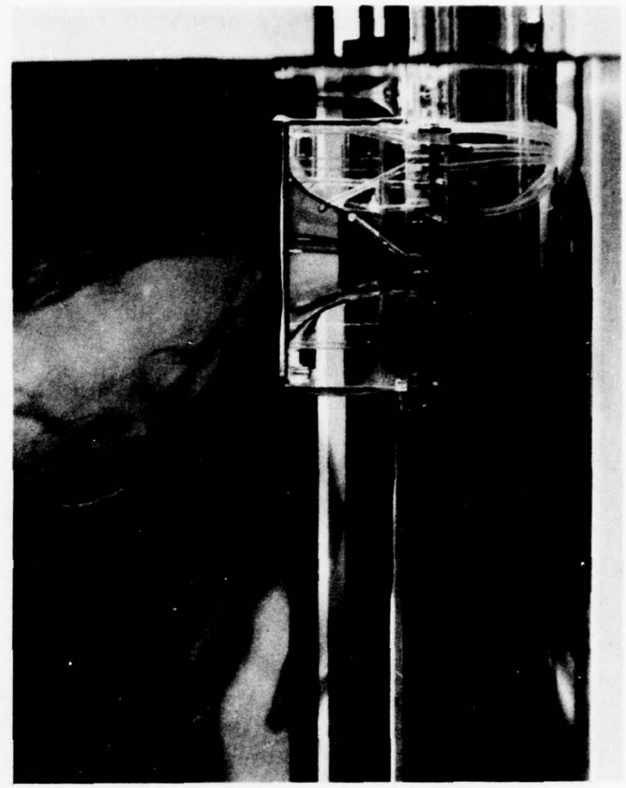


Discharge 1,050 cfs, pool elev 1789

Photograph 12. Patterns of flow entering bypass intake; bulkhead slot covered.



Vortex at intake; bulkhead slot covered,
pool elev 1789



Drawdown over open bulkhead slot;
pool elev 1782

Photograph 13. Patterns of flow entering bypass intake; discharge 1,050 cfs.

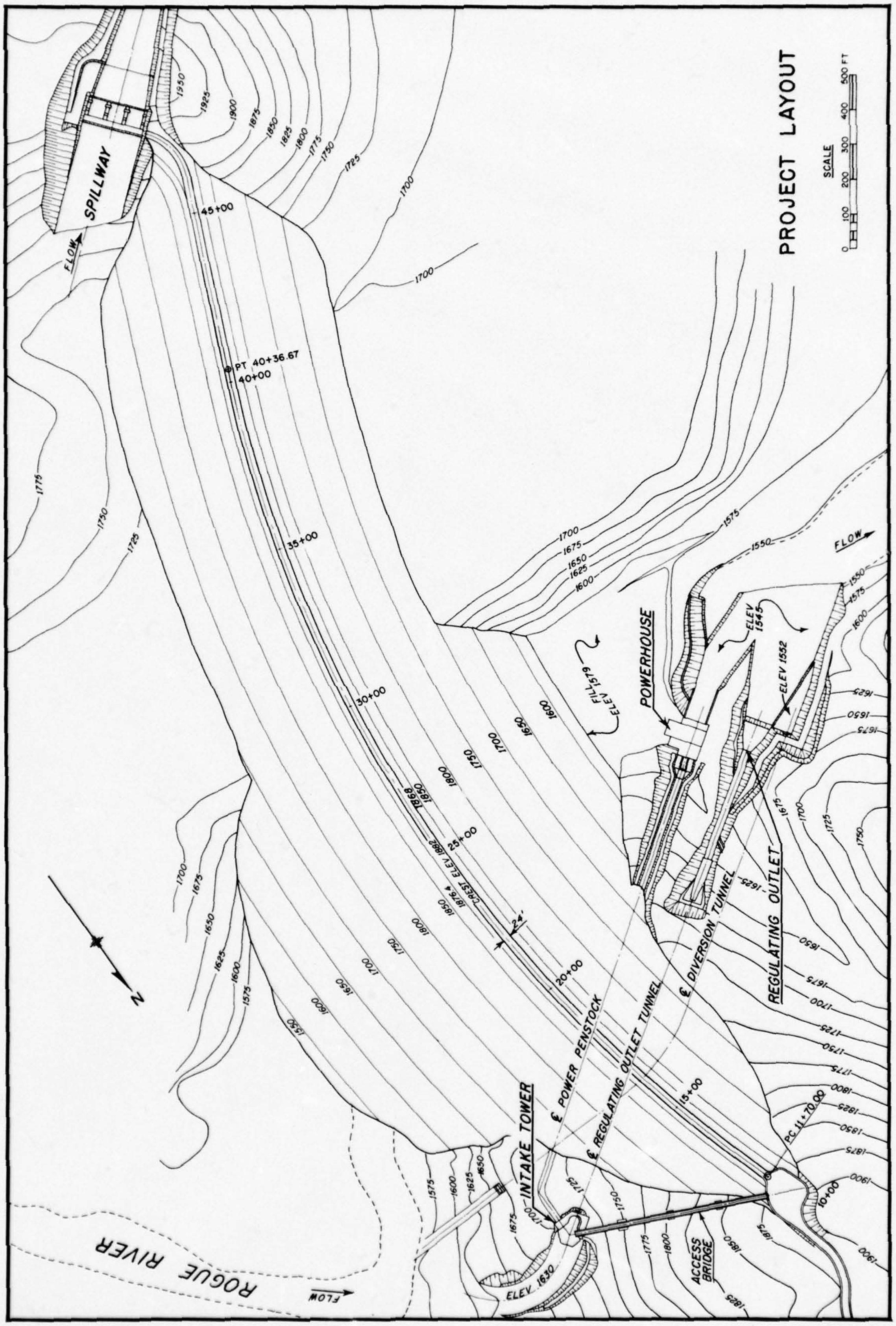
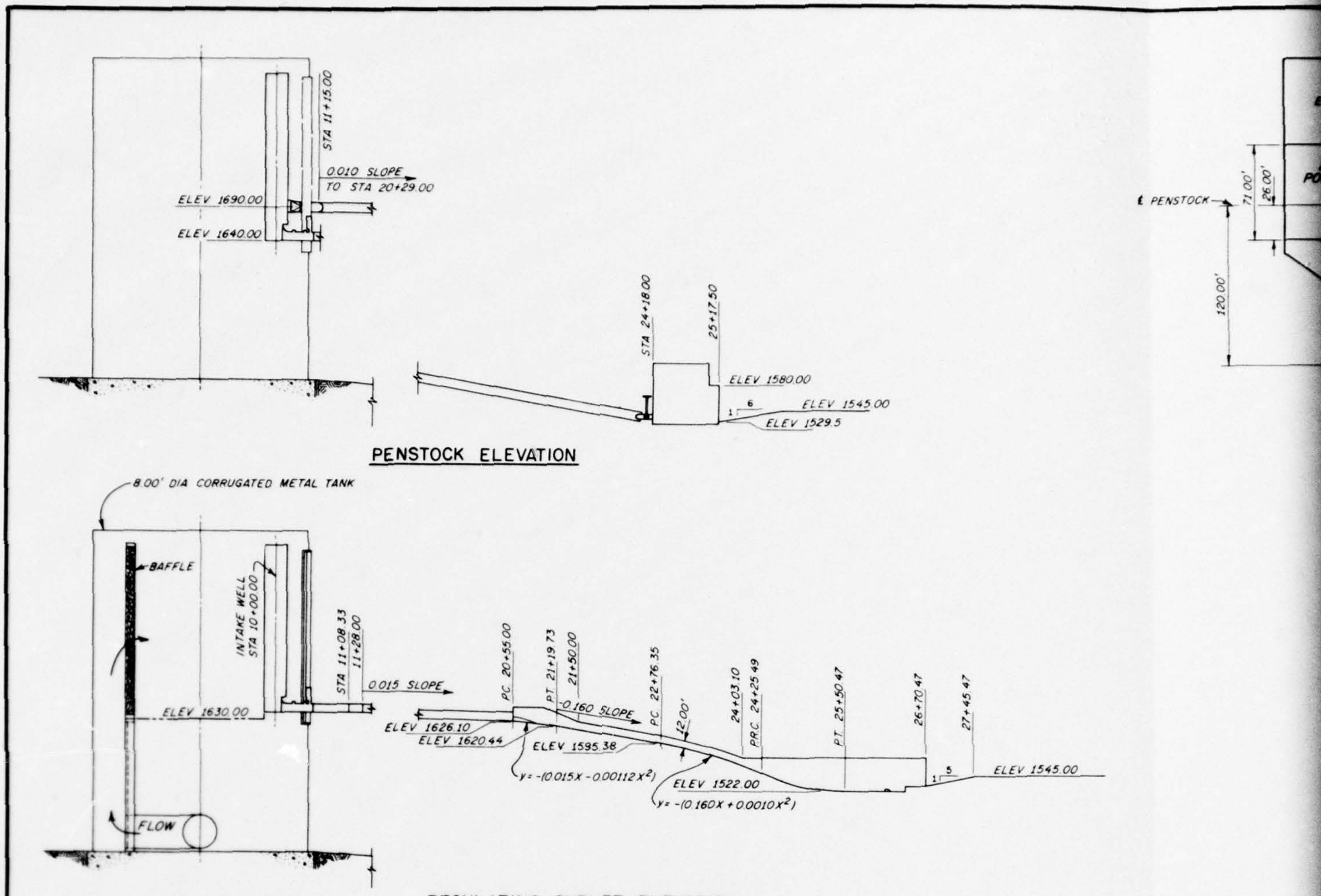
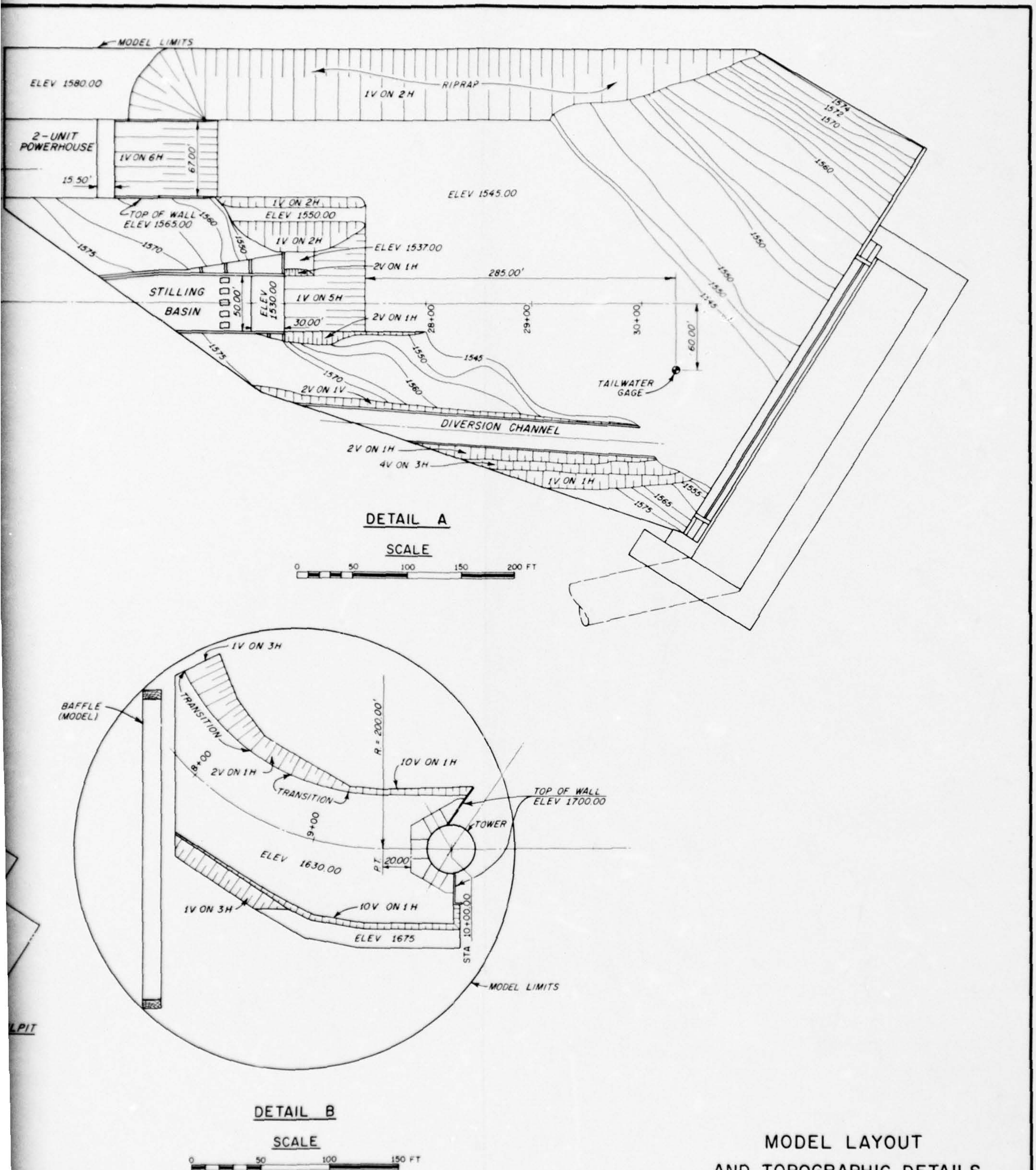

PROJECT LAYOUT
SCALE
0 100 200 300 400 500 FT
SPILLWAY
FLOW
45+00
PT 40+36.67
40+00
35+00
30+00
25+00
20+00
15+00
CREST ELEV 1882
24'
FILL ELEV 1579
POWERHOUSE
ELEV 1545
ELEV 1552
REGULATING OUTLET
℄ DIVERSION TUNNEL
℄ REGULATING OUTLET TUNNEL
℄ POWER PENSTOCK
INTAKE TOWER
PC 11+70.00
10+00
ACCESS BRIDGE
ELEV 1630
ROGUE RIVER
FLOW
N

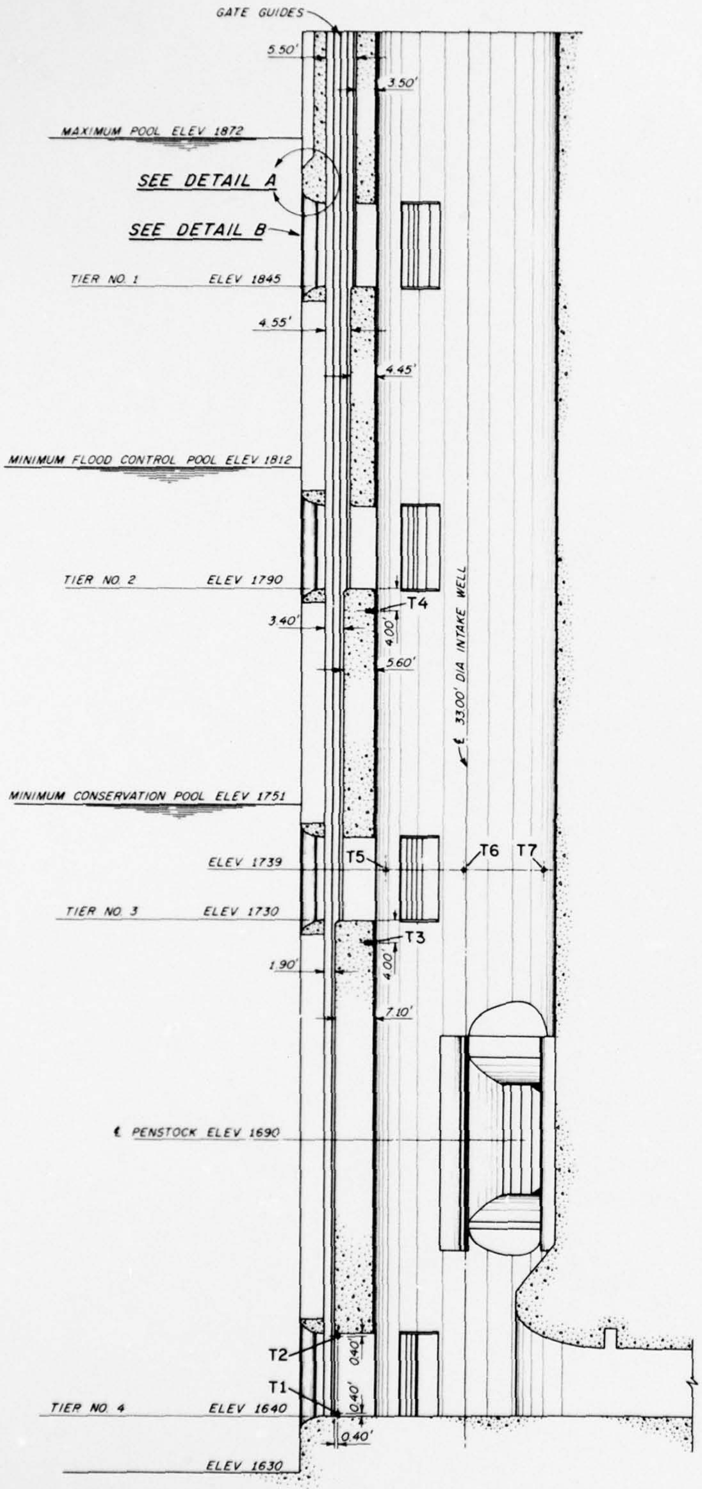
PLATE 1



STA 11+15.00
0.010 SLOPE
TO STA 20+29.00
ELEV 1690.00
ELEV 1640.00
STA 24+18.00
25+17.50
ELEV 1580.00
ELEV 1545.00
ELEV 1529.5
PENSTOCK ELEVATION
8.00' DIA CORRUGATED METAL TANK
BAFFLE
INTAKE WELL
STA 10+00.00
STA 11+08.33
11+28.00
0.015 SLOPE
ELEV 1630.00
FLOW
PC 20+55.00
PT 21+19.73
21+50.00
-0.160 SLOPE
PC 22+76.35
12.00'
24+03.10
PRC 24+25.49
PT 25+50.47
26+70.47
27+45.47
ELEV 1626.10
ELEV 1620.44
ELEV 1595.38
$y = -(0.015X - 0.00112X^2)$
ELEV 1522.00
$y = -(0.160X + 0.0010X^2)$
ELEV 1545.00
REGULATING OUTLET ELEVATION
TOPOGRAPHY
SEE DETAIL B
PC STA 11+15.26
PT STA 11+72.86
15.00' DIA PENSTOCK
POWERHOUSE
TOPOGRAPHY
SEE DETAIL A
PENSTOCK
PLATE 4
12.50' DIA. TUNNEL
STILLING BASIN
PLATE 9
TUNNEL TRANSITION
PLATE 7
CHUTE TRANSITION
PLATE 8
INTAKE
PLATES 3, 5, AND 6
TOWER
PLATE 3
FLOW
STA 10+00.00
℄ INTAKE WELL
PLAN
SCALE
0
100
200
300
400 FT
TAILPIT
℄ PENSTOCK
71.00'
26.00'
120.00'



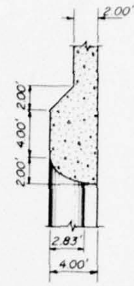
MODEL LAYOUT
AND TOPOGRAPHIC DETAILS
ORIGINAL DESIGN



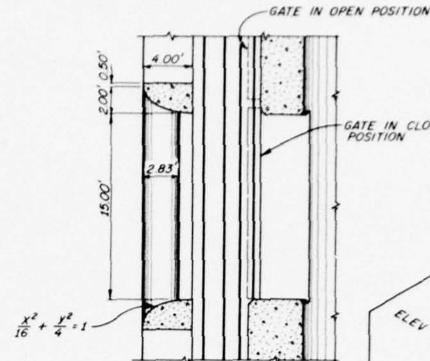
SECTION A-A

SCALE

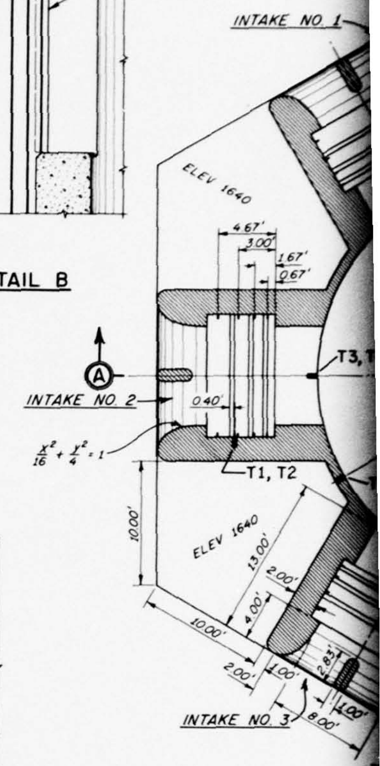
0 10 20 30 40 50 FT

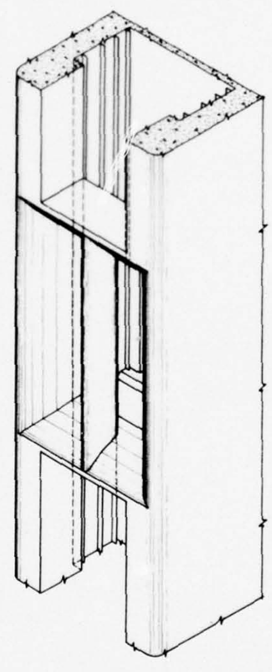


DETAIL A



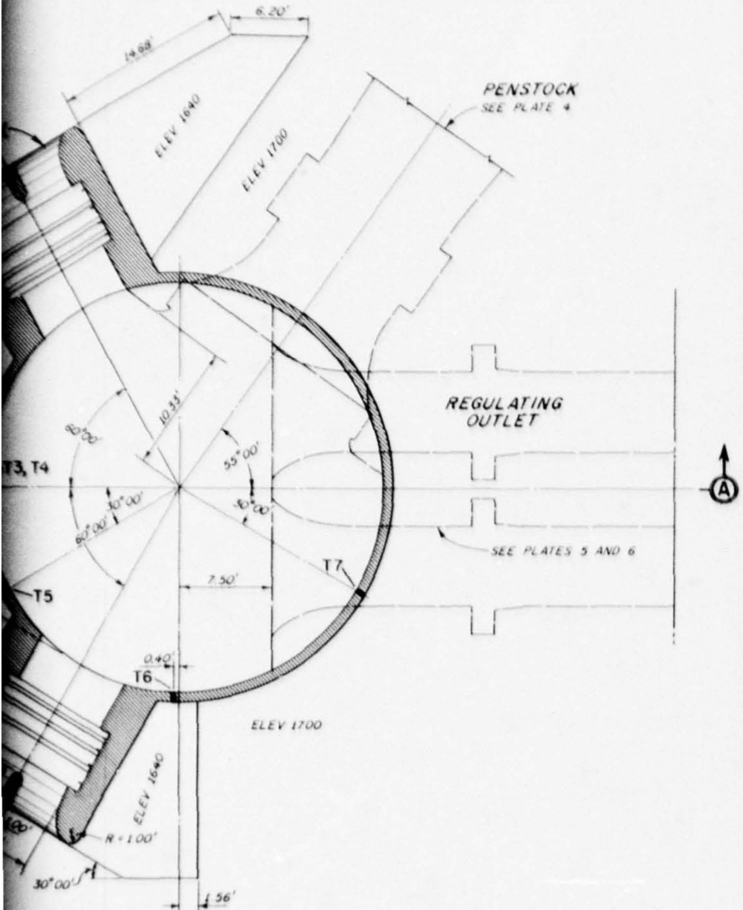
DETAIL B





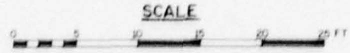
ISOMETRIC VIEW OF INTAKE PORTAL

GATE SCHEDULE			
TIER NO.	HEIGHT	WIDTH	THICKNESS
1	15.58'	8.83'	0.87'
2	15.58'	8.83'	1.07'
3	15.58'	8.83'	1.42'
4	18.08'	8.83'	1.82'



PLAN AT ELEVATION 1850

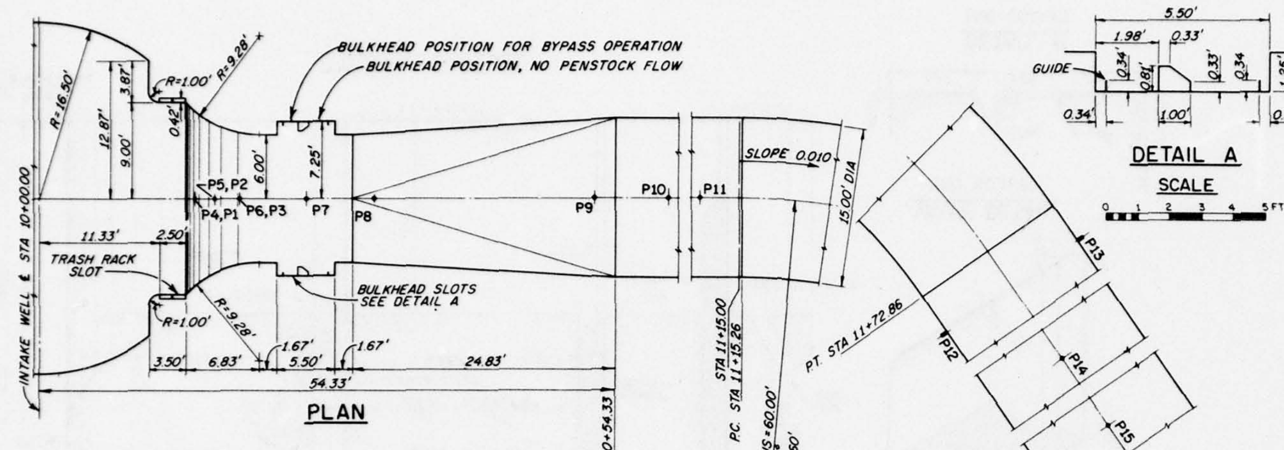
TIER NO. 1

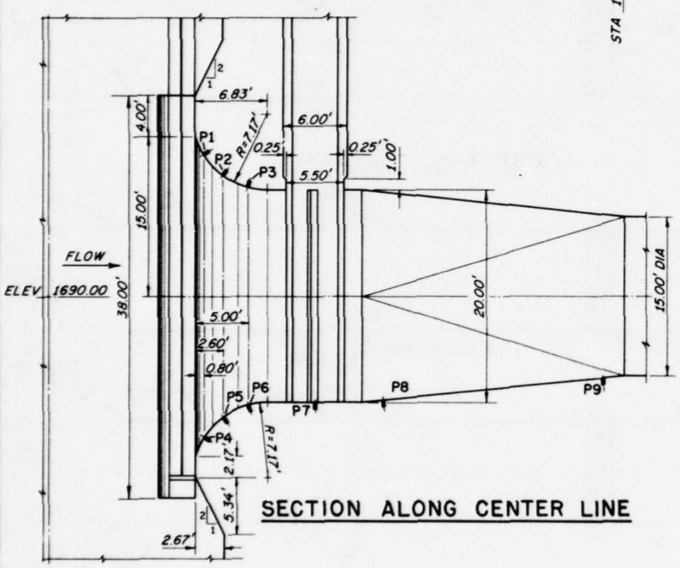


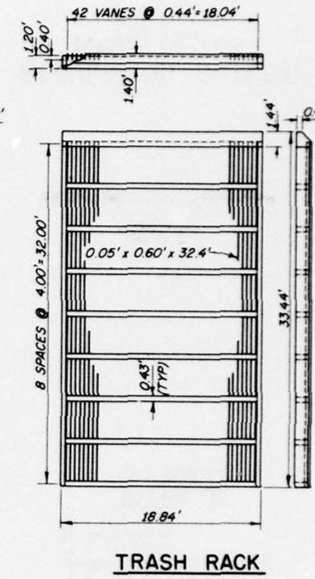
INTAKE TOWER DETAILS
AND PIEZOMETER LOCATIONS

PLATE 3

2







PIEZOMETER LOCATIONS

PIEZ. NO.	STATION	ELEVATION
P1	10 + 14.63	1703.30
P2	10 + 16.43	1701.38
P3	10 + 18.83	1700.24
P4	10 + 14.63	1676.70
P5	10 + 16.43	1678.62
P6	10 + 18.83	1679.76
P7	10 + 25.06	1680.00
P8	10 + 31.50	1680.20
P9	10 + 52.33	1682.30
P10	10 + 59.33	1682.50
P11	11 + 11.26	1682.50
P12	11 + 76.85	1689.38
P13	11 + 76.85	1689.38
P14	13 + 65.63	1679.99
P15	15 + 56.02	1678.09

SCALE

0 5 10 15 20 25 FT

PENSTOCK

DETAILS AND PIEZOMETER LOCATIONS

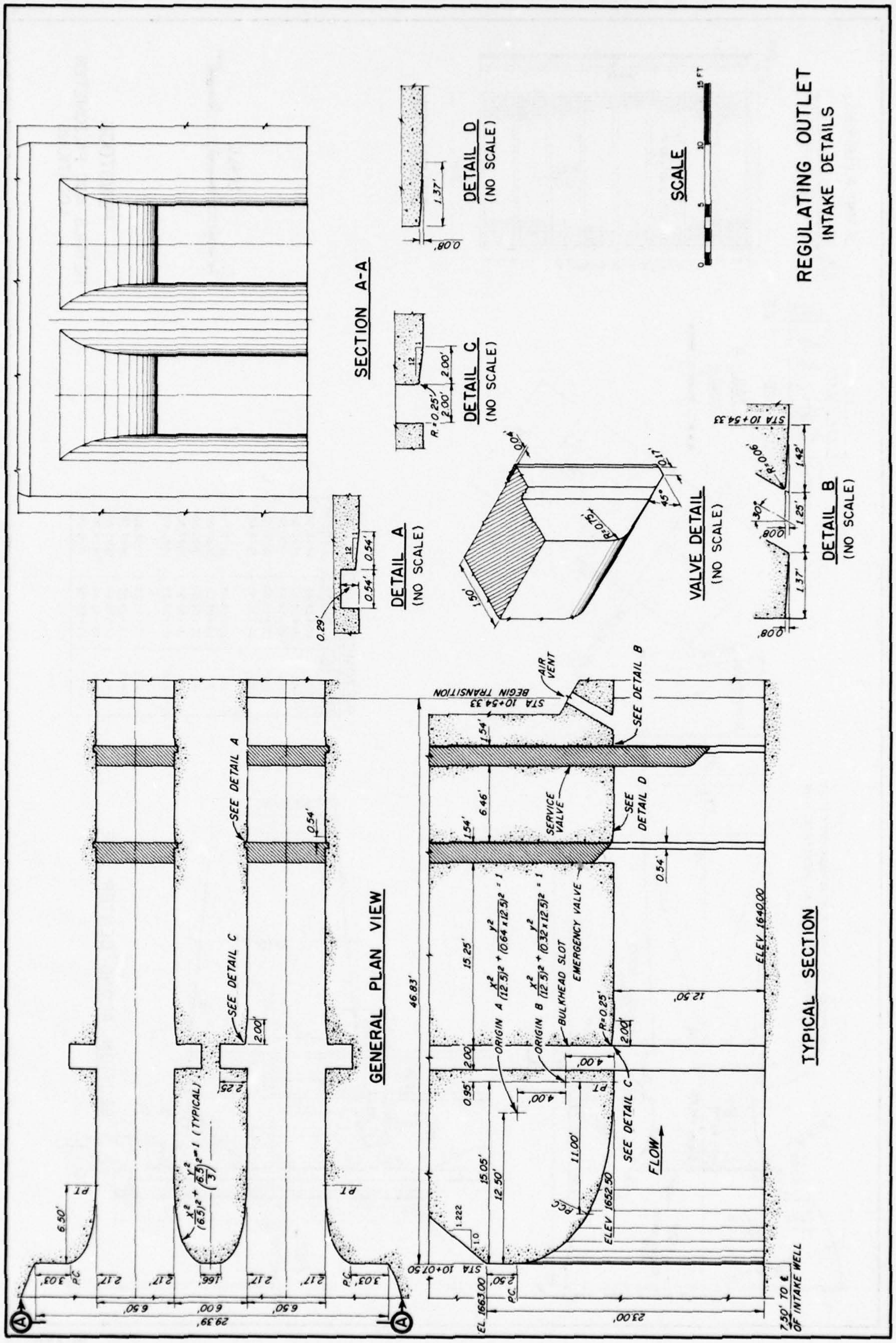
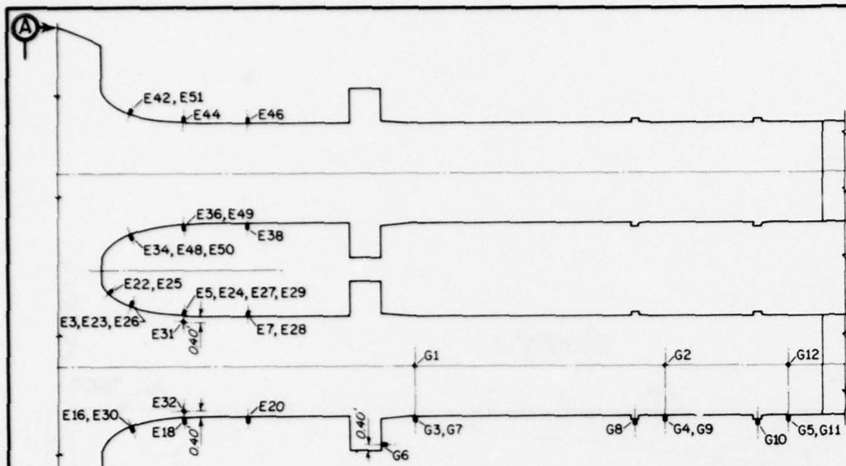
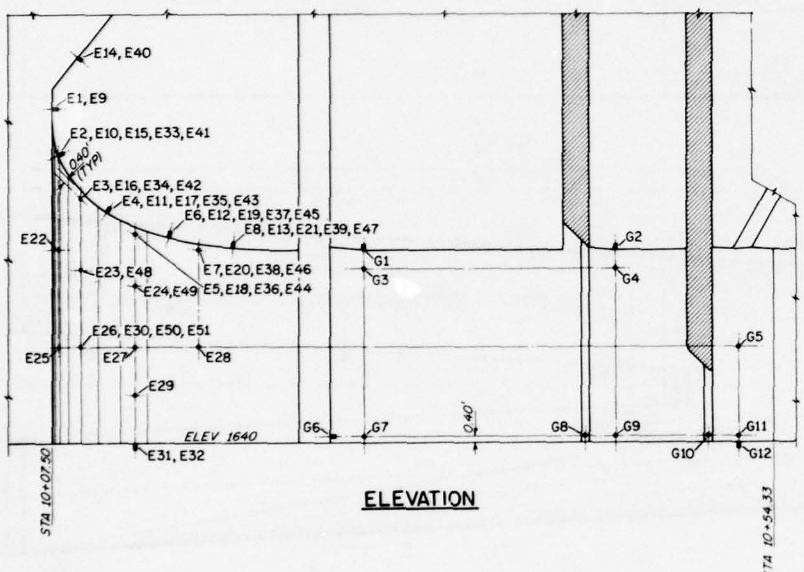

REGULATING OUTLET
INTAKE DETAILS
SECTION A-A
DETAIL A
(NO SCALE)
DETAIL B
(NO SCALE)
DETAIL C
(NO SCALE)
DETAIL D
(NO SCALE)
VALVE DETAIL
(NO SCALE)
SCALE
GENERAL PLAN VIEW
TYPICAL SECTION
SEE DETAIL A
SEE DETAIL B
SEE DETAIL C
SEE DETAIL D
SERVICE VALVE
EMERGENCY VALVE
BULKHEAD SLOT
AIR VENT
STA 10+54.33 BEGIN TRANSITION
STA 10+07.50
EL 1663.00
ELEV 1652.50
ELEV 1640.00
FLOW
7.50' TO ℄ OF INTAKE WELL
ORIGIN A
ORIGIN B

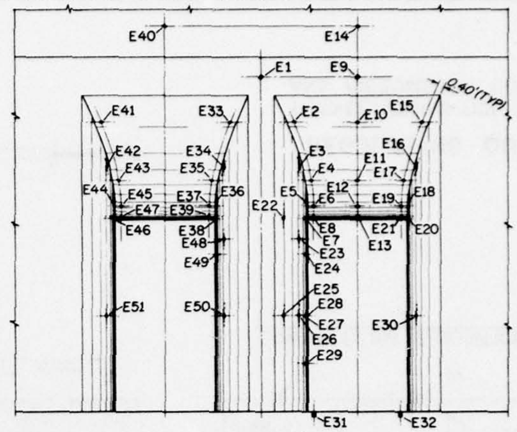
PLATE 5



PLAN



ELEVATION



SECTION A-A

PIEZOMETER LOCATIONS								
PIEZ NO.	STATION	ELEVATION	PIEZ NO.	STATION	ELEVATION	PIEZ NO.	STATION	ELEVATION
E1	10+07.50	1661.70	E23	10+09.34	1651.25	E45	10+14.94	1653.33
E2	10+07.90	1658.49	E24	10+12.82	1650.25	E46	10+16.98	1652.52
E3	10+09.34	1655.76	E25	10+07.90	1646.25	E47	10+19.18	1652.65
E4	10+10.98	1654.96	E26	10+09.34	1646.25	E48	10+09.34	1651.25
E5	10+12.82	1653.55	E27	10+12.82	1646.25	E49	10+12.82	1650.25
E6	10+14.94	1653.33	E28	10+16.98	1646.25	E50	10+09.34	1646.25
E7	10+16.98	1652.52	E29	10+12.82	1643.12	E51	10+09.34	1646.25
E8	10+19.18	1652.65	E30	10+09.34	1646.25	G1	10+27.70	1652.50
E9	10+07.50	1661.70	E31	10+12.82	1640.00	G2	10+44.01	1652.50
E10	10+07.90	1658.49	E32	10+12.82	1640.00	G3	10+27.70	1651.30
E11	10+10.98	1654.96	E33	10+07.90	1658.49	G4	10+44.01	1651.30
E12	10+14.94	1653.33	E34	10+09.34	1655.76	G5	10+52.01	1646.25
E13	10+19.18	1652.65	E35	10+10.98	1654.96	G6	10+25.50	1640.40
E14	10+09.14	1665.00	E36	10+12.82	1653.55	G7	10+27.70	1640.40
E15	10+07.90	1658.49	E37	10+14.94	1653.33	G8	10+42.03	1640.40
E16	10+09.34	1655.76	E38	10+16.98	1652.52	G9	10+44.01	1640.40
E17	10+10.98	1654.96	E39	10+19.18	1652.65	G10	10+50.03	1640.40
E18	10+12.82	1653.55	E40	10+09.14	1665.00	G11	10+52.01	1640.40
E19	10+14.94	1653.33	E41	10+07.90	1658.49	G12	10+52.01	1640.00
E20	10+16.98	1652.52	E42	10+09.34	1655.76			
E21	10+19.18	1652.65	E43	10+10.98	1654.96			
E22	10+07.90	1652.57	E44	10+12.82	1653.55			

NOTE

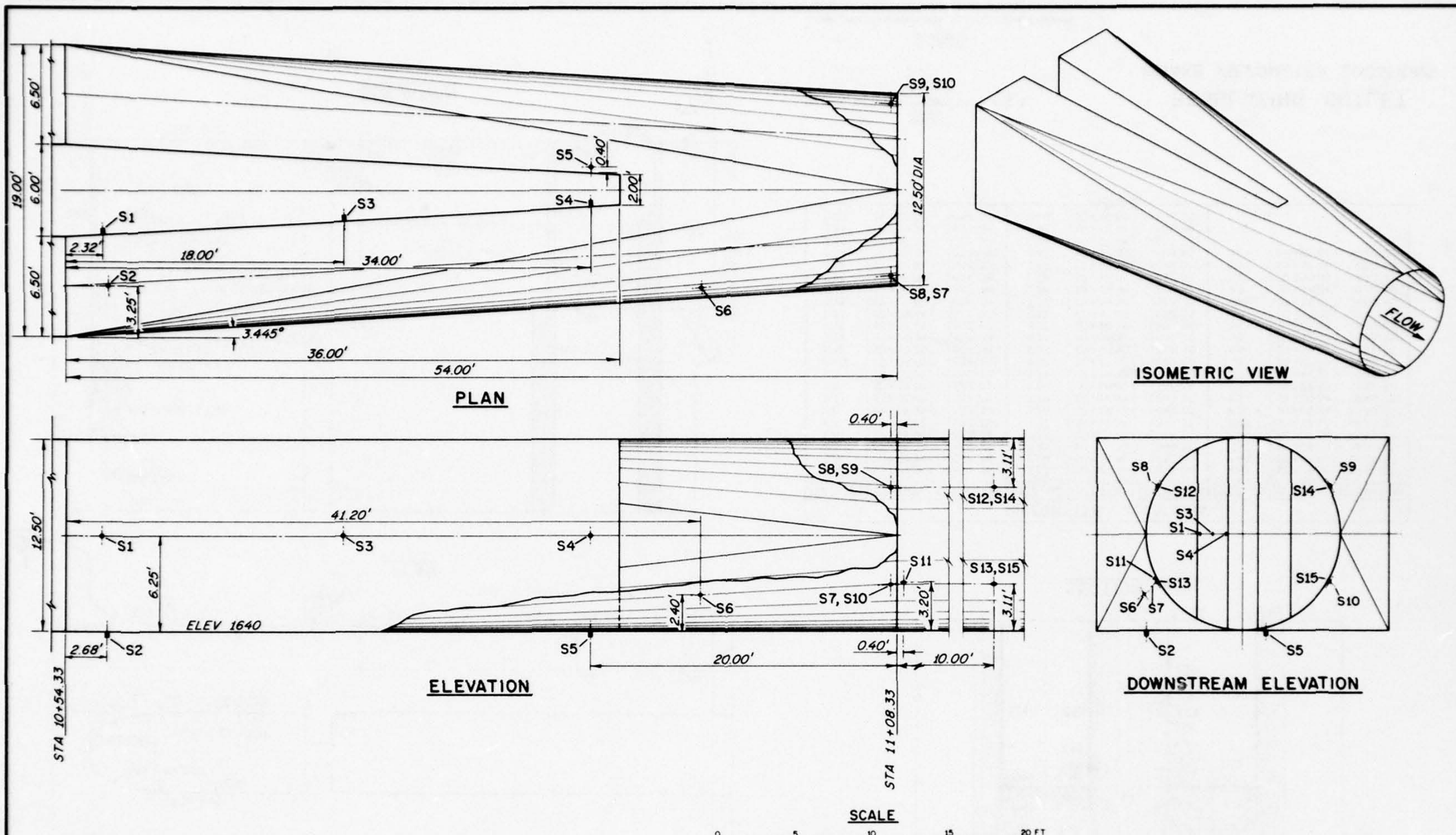
INTAKE DETAILS SHOWN ON PLATE 5.

SCALE

0 5 10 15 20 FT

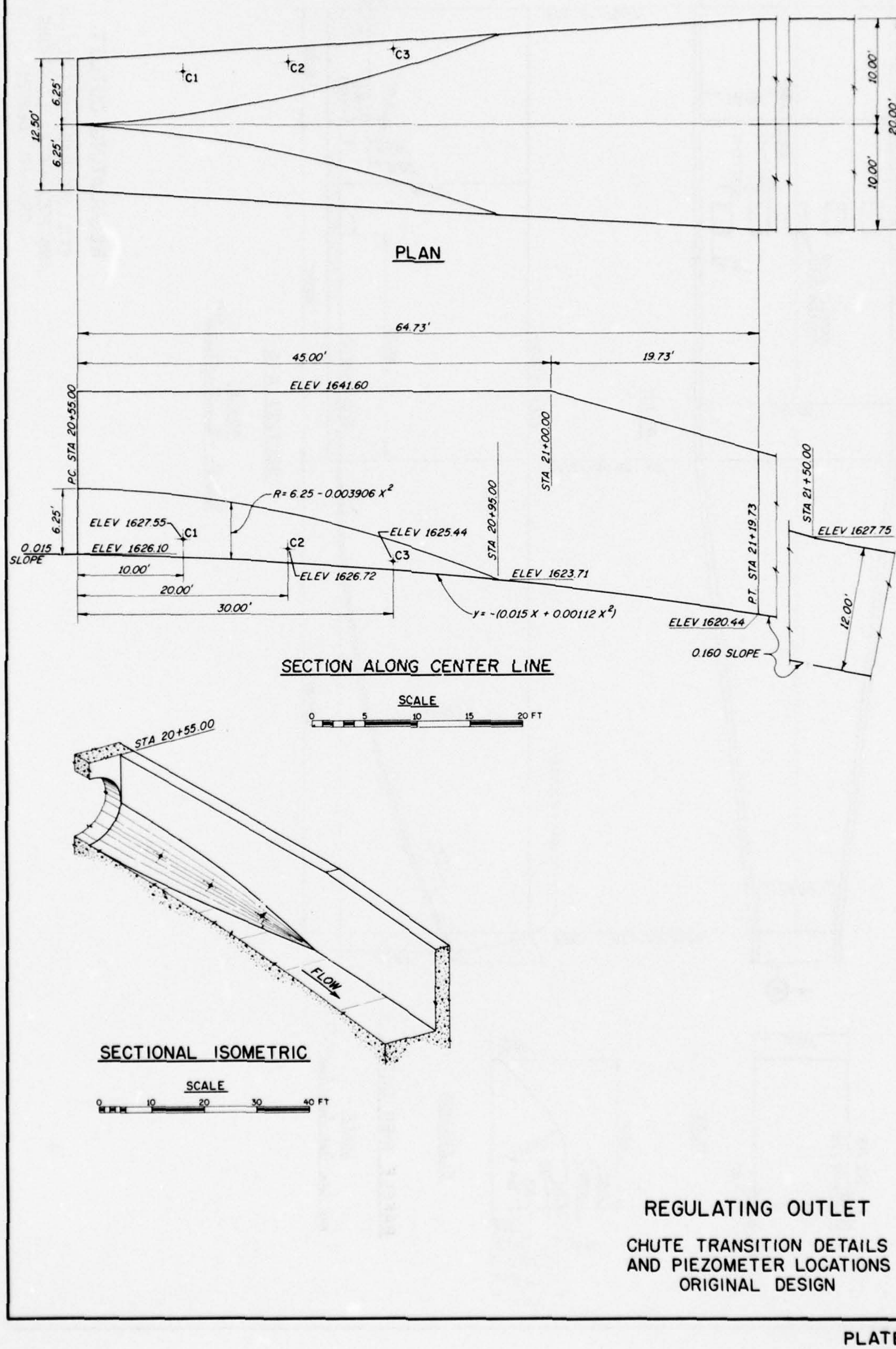
REGULATING OUTLET

INTAKE PIEZOMETER LOCATIONS



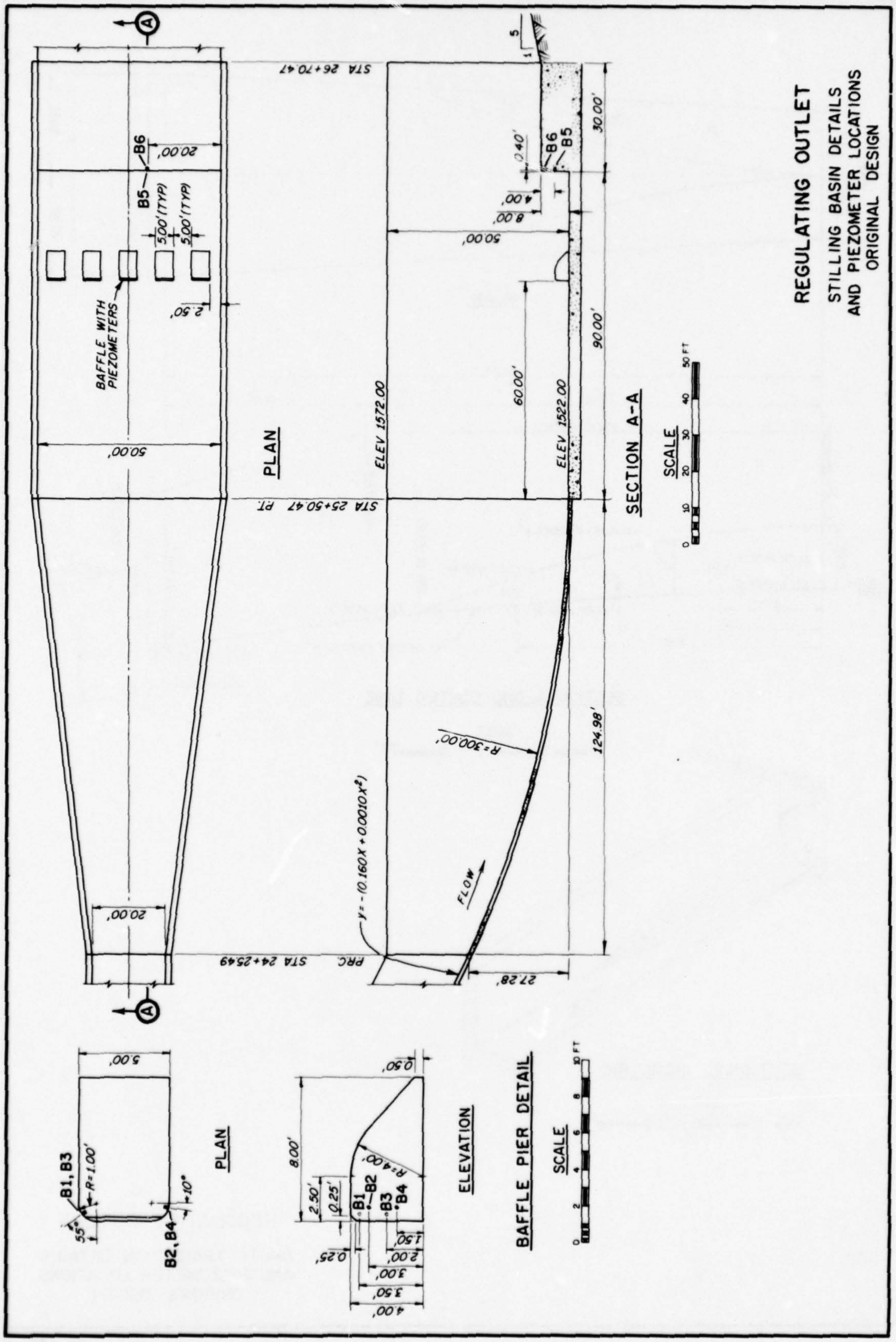
REGULATING OUTLET

TUNNEL TRANSITION DETAILS AND PIEZOMETER LOCATIONS



REGULATING OUTLET

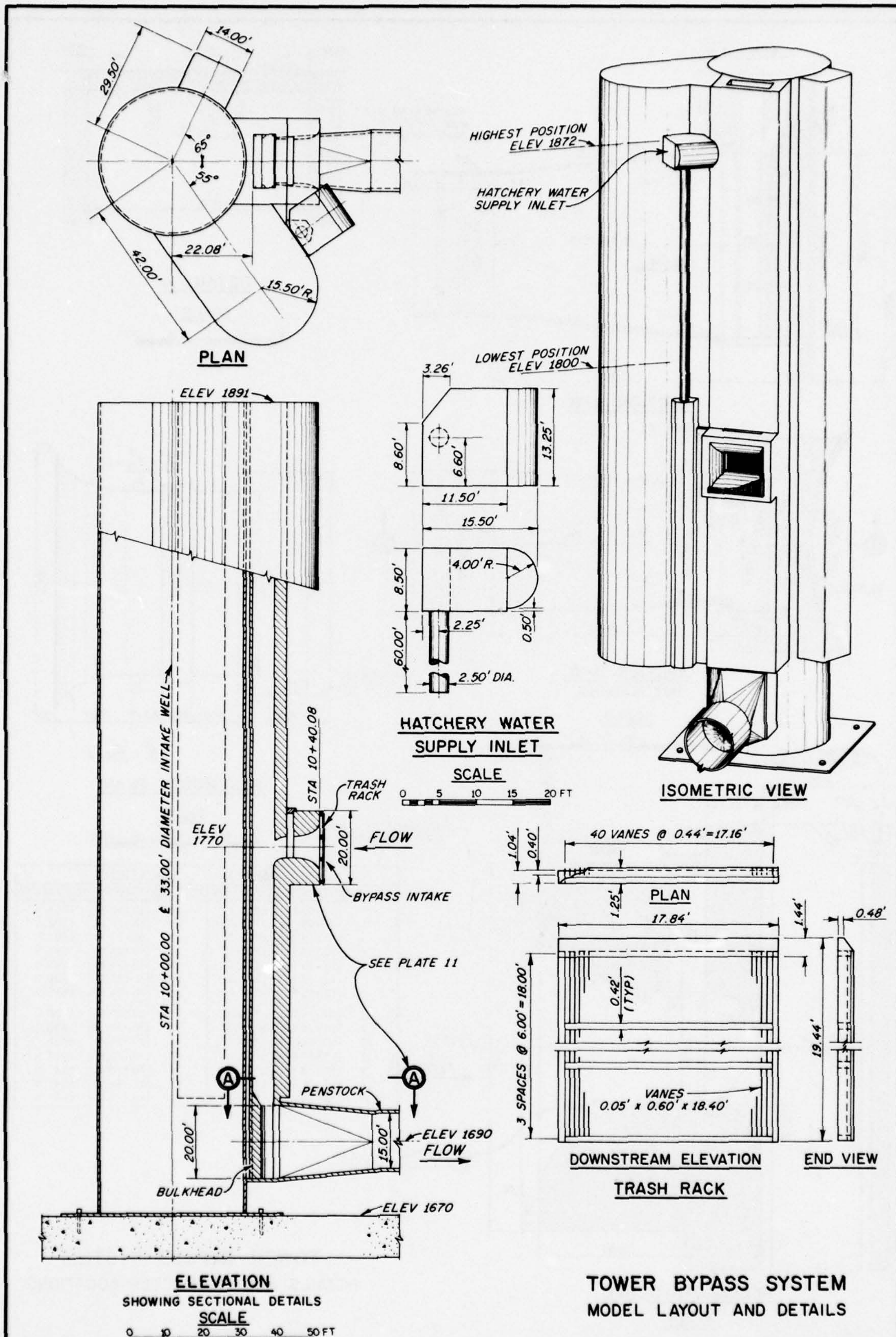
CHUTE TRANSITION DETAILS
AND PIEZOMETER LOCATIONS
ORIGINAL DESIGN



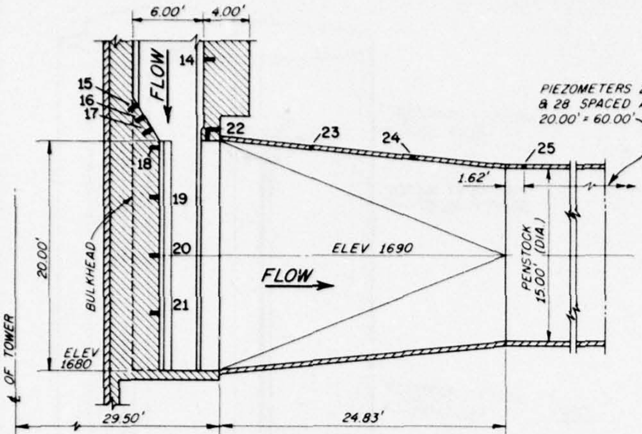
REGULATING OUTLET

STILLING BASIN DETAILS AND PIEZOMETER LOCATIONS

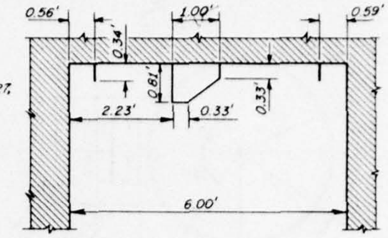
ORIGINAL DESIGN



TOWER BYPASS SYSTEM
MODEL LAYOUT AND DETAILS



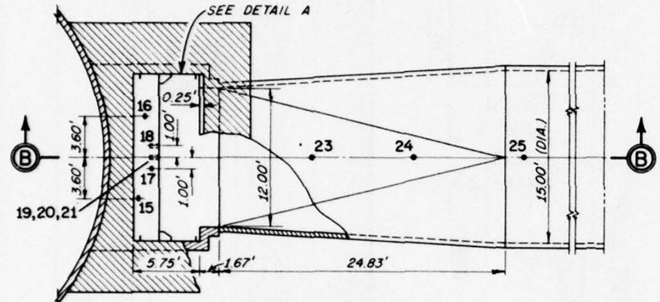
SECTION B-B



DETAIL A

SCALE

0 1 2 3 4 FT

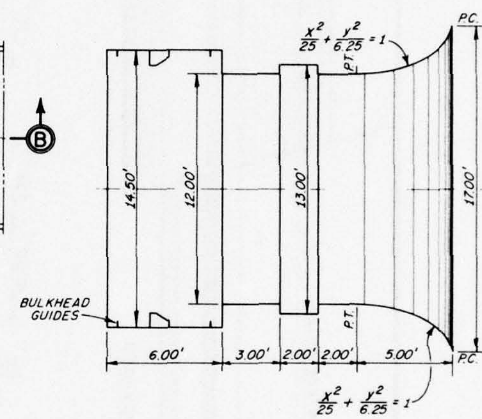


SECTION A-A

(SEE PLATE 10)

SCALE

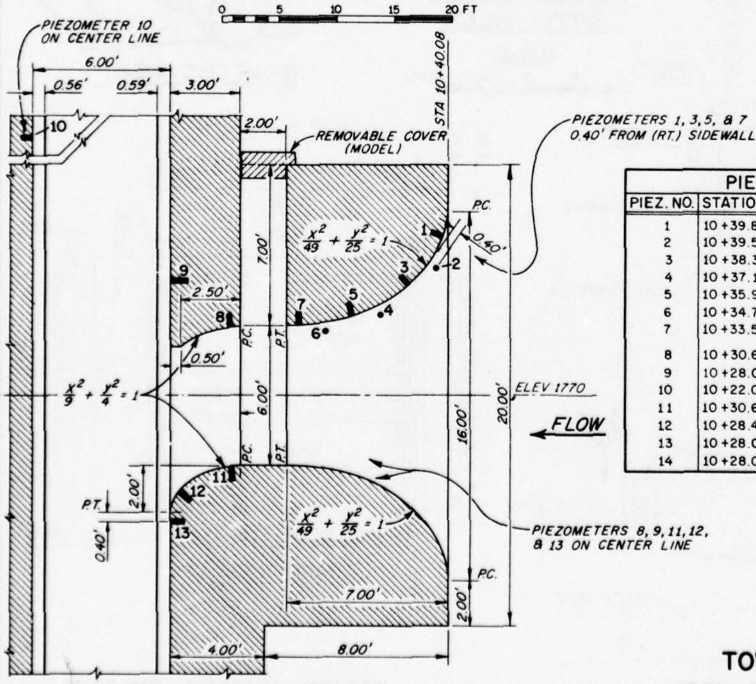
0 5 10 15 20 FT



BELLMOUTH PLAN

SCALE

0 2 4 6 8 10 FT



BELLMOUTH DETAIL

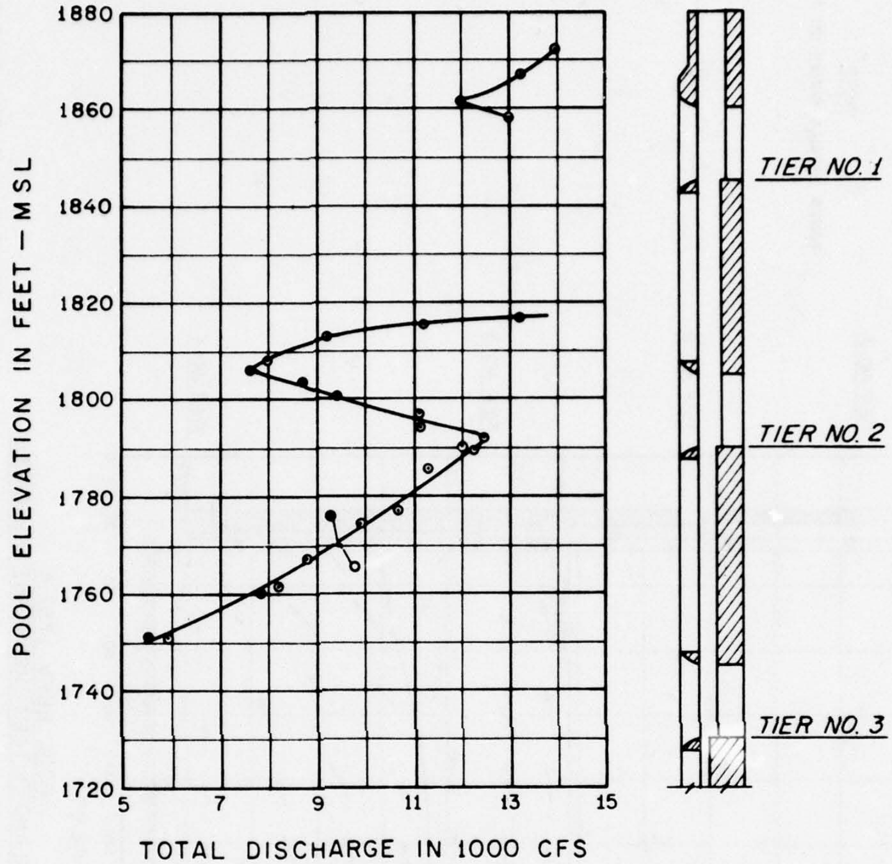
SCALE

0 2 4 6 8 10 FT

PIEZOMETER			LOCATIONS		
PIEZ. NO.	STATION	ELEVATION	PIEZ. NO.	STATION	ELEVATION
1	10+39.88	1776.8	15	10+22.52	1703.1
2	10+39.56	1775.5	16	10+23.12	1702.1
3	10+38.36	1774.7	17	10+23.72	1701.0
4	10+37.16	1773.5	18	10+24.32	1699.5
5	10+35.96	1773.4	19	10+24.32	1695.0
6	10+34.76	1772.8	20	10+24.32	1690.0
7	10+33.56	1773.0	21	10+24.32	1685.0
8	10+30.68	1773.0	22	10+28.35	1700.0
9	10+28.08	1775.0	23	10+37.41	1699.2
10	10+22.08	1790.0	24	10+46.45	1698.3
11	10+30.68	1767.0	25	10+55.95	1697.5
12	10+28.48	1765.7	26	10+75.95	1697.5
13	10+28.08	1764.6	27	10+95.95	1697.5
14	10+28.08	1707.1	28	11+15.95	1697.5

TOWER BYPASS SYSTEM

DETAILS AND PIEZOMETER LOCATIONS



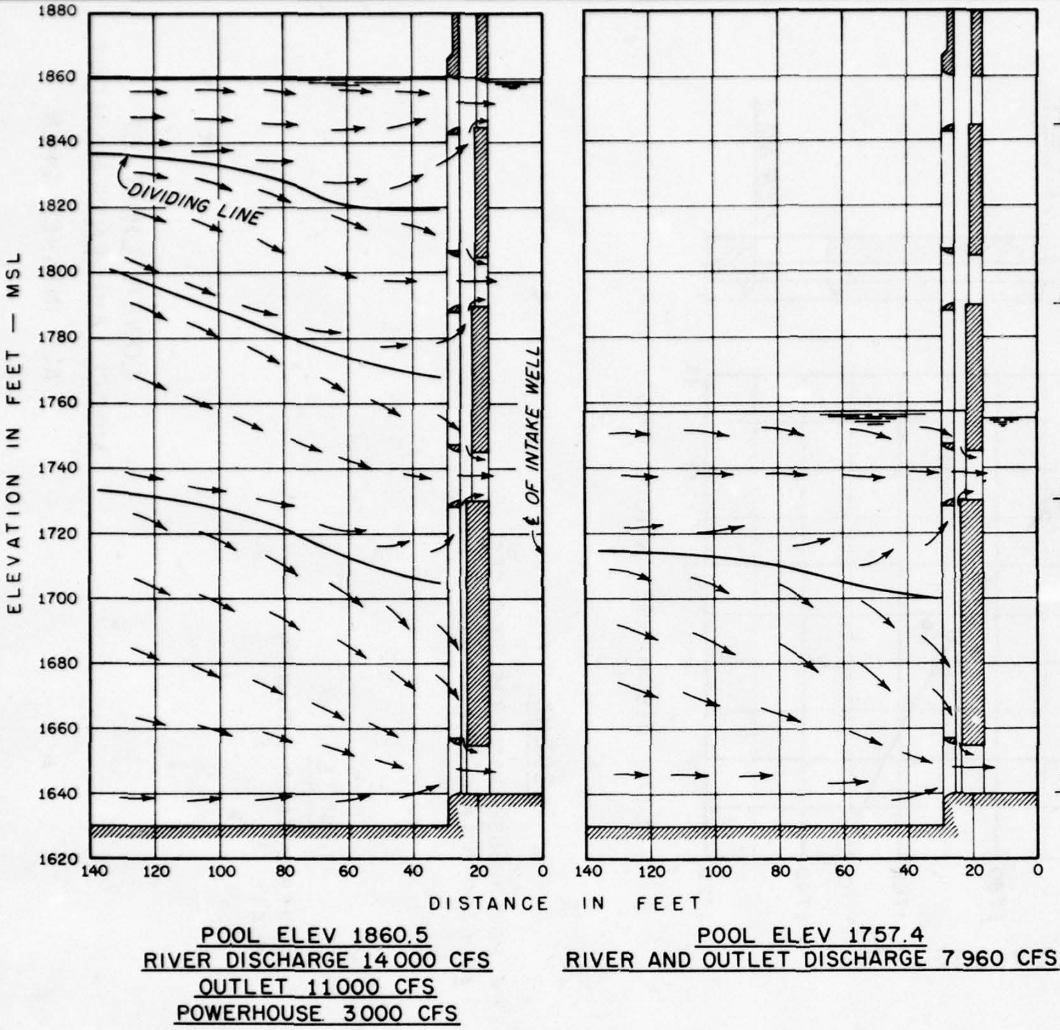
LEGEND

- ○ POWERHOUSE DISCHARGE 3000 CFS
- ● POWERHOUSE CLOSED.

NOTE

TOWER DETAILS SHOWN ON PLATE 3.

LOWER LIMIT OF
MODEL AIR ENTRAINMENT
ALL INTAKES OPEN

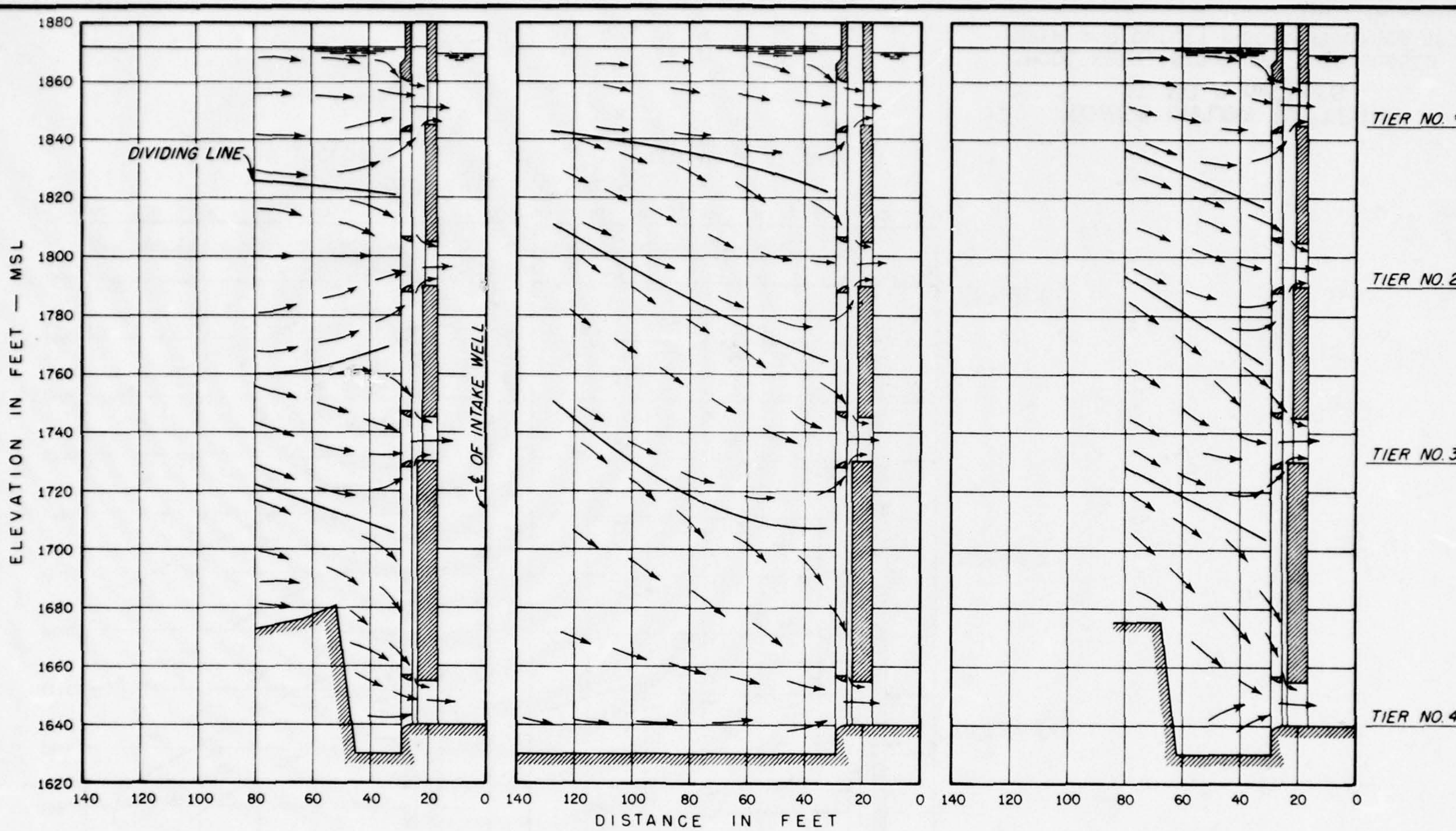


NOTE

TOWER DETAILS SHOWN ON PLATE 3.

TOWER INFLOW PATTERNS
AT NO. 2 INTAKES

POOL ELEVATION AND OUTLET
DISCHARGE VARIED, ALL INTAKES OPEN



NO. 1 INTAKES

NO. 2 INTAKES

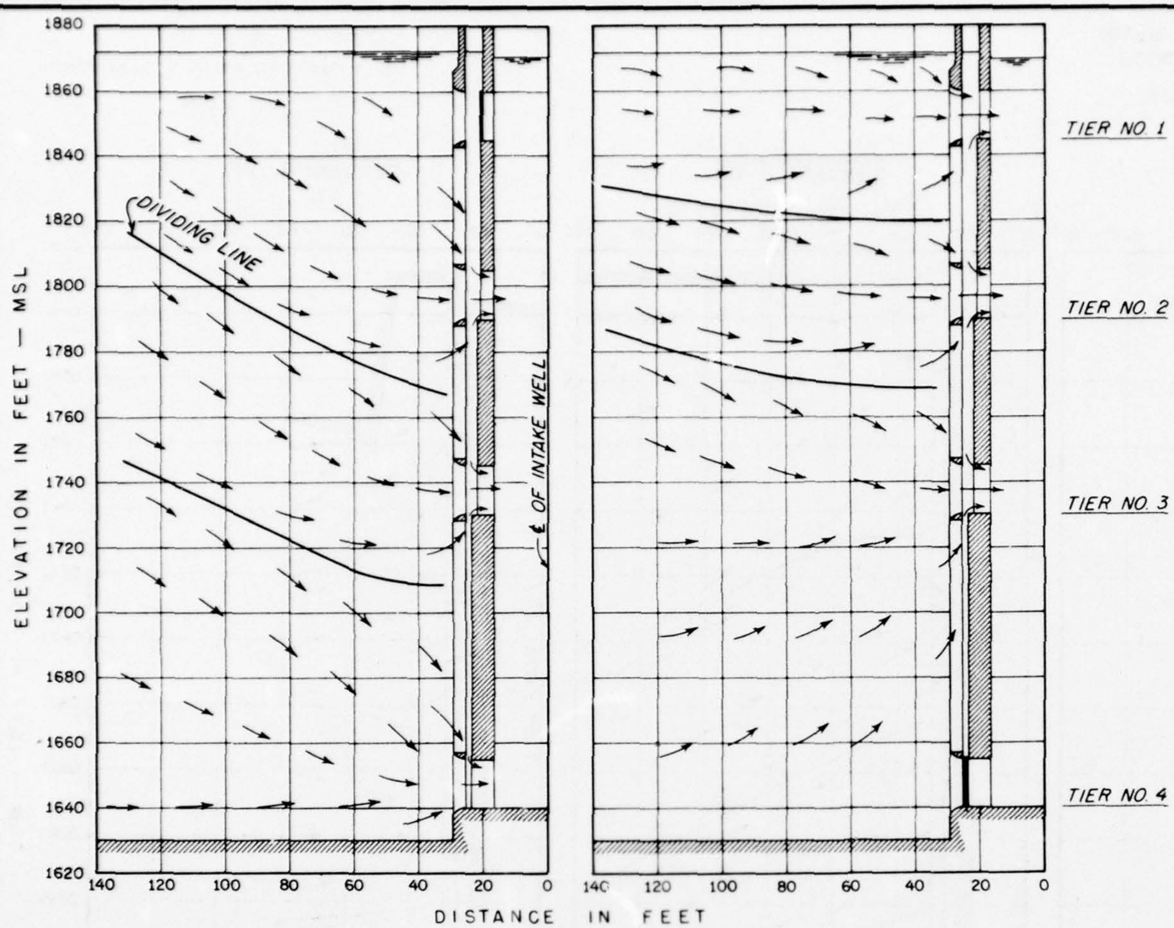
NO. 3 INTAKES

NOTE

TOWER DETAILS SHOWN ON PLATE 3.

TOWER INFLOW PATTERNS

POOL ELEV 1872.0, ALL INTAKES OPEN
RIVER AND OUTLET DISCHARGE 10000 CFS



TIER NO. 1 CLOSED

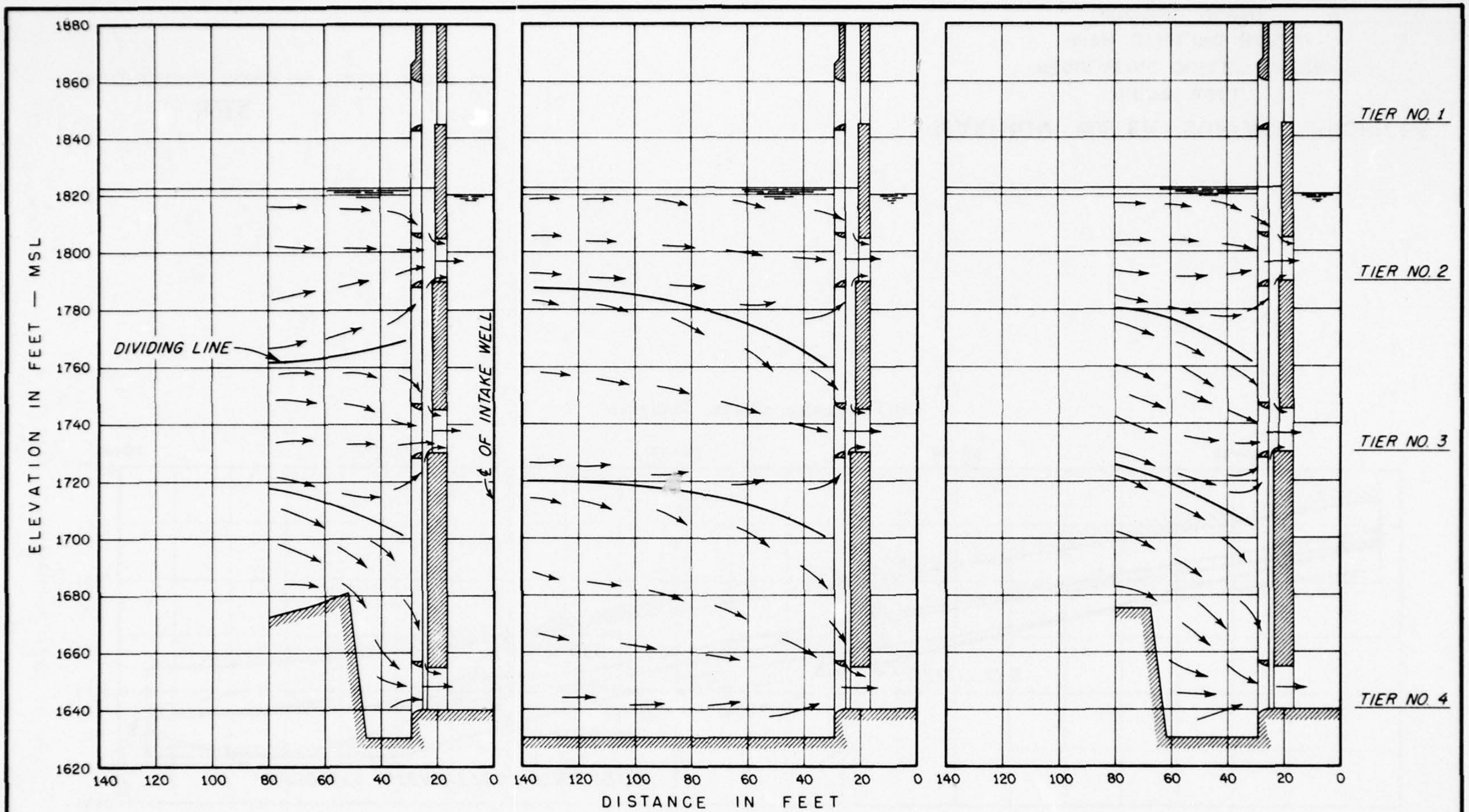
TIER NO. 4 CLOSED

NOTE

TOWER DETAILS SHOWN ON PLATE 3.

TOWER INFLOW PATTERNS
AT NO. 2 INTAKES

POOL ELEV 1872.0, ONE TIER CLOSED
RIVER AND OUTLET DISCHARGE 10 000 CFS



NO. 1 INTAKES

NO. 2 INTAKES

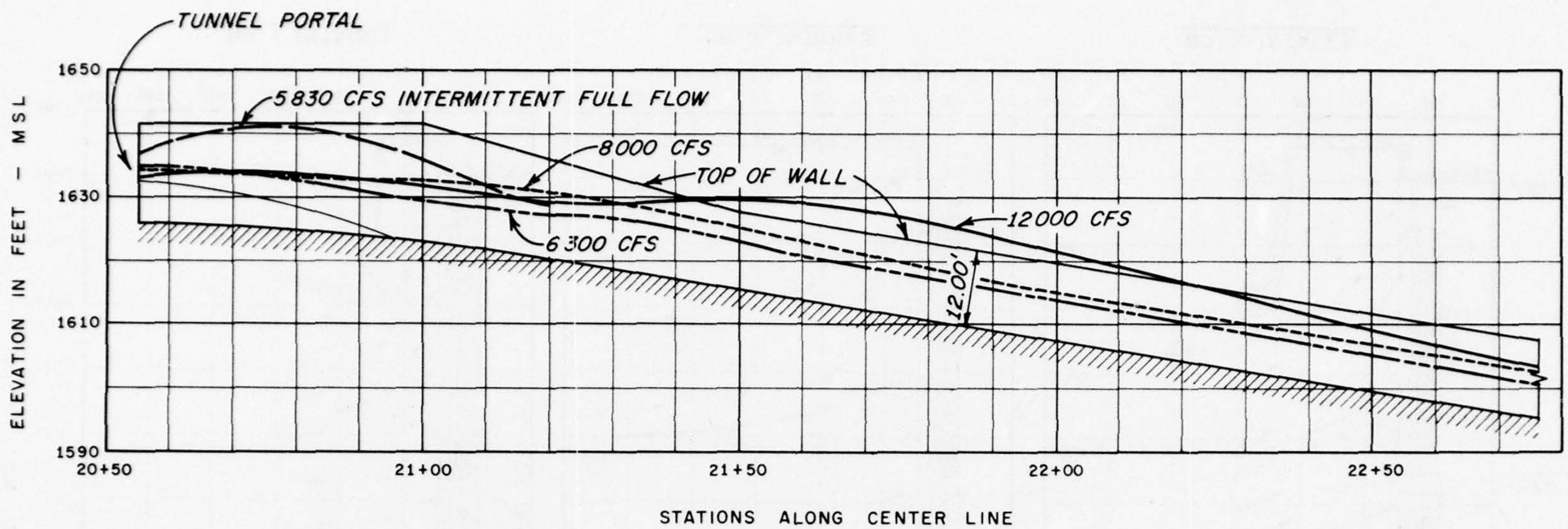
NO. 3 INTAKES

NOTE

TOWER DETAILS SHOWN ON PLATE 3.

TOWER INFLOW PATTERNS

POOL ELEV 1822.8, ALL INTAKES OPEN
RIVER AND OUTLET DISCHARGE 10 000 CFS



NOTE

CHUTE DETAILS SHOWN ON PLATES 2 AND 8

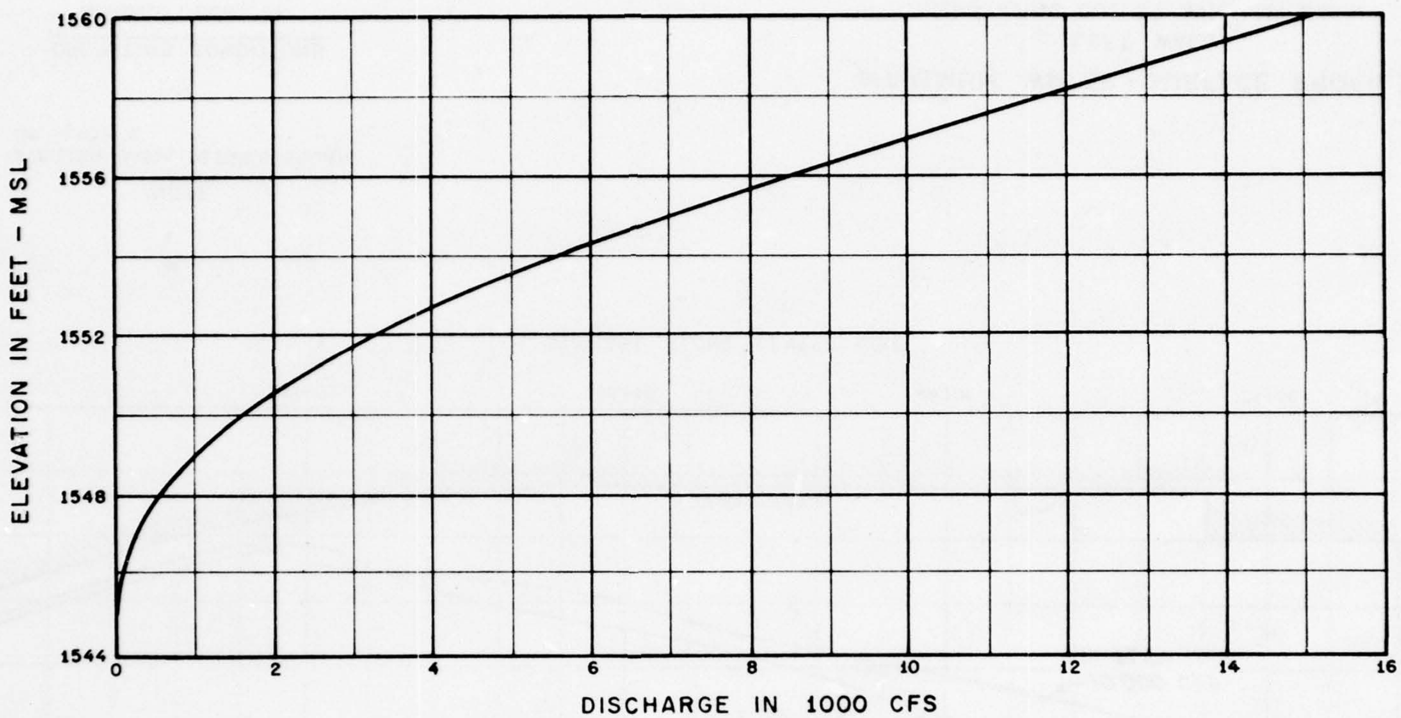
MAXIMUM WATER-SURFACE PROFILES

LEFT WALL

REGULATING OUTLET CHUTE

WITH STILLING BASIN

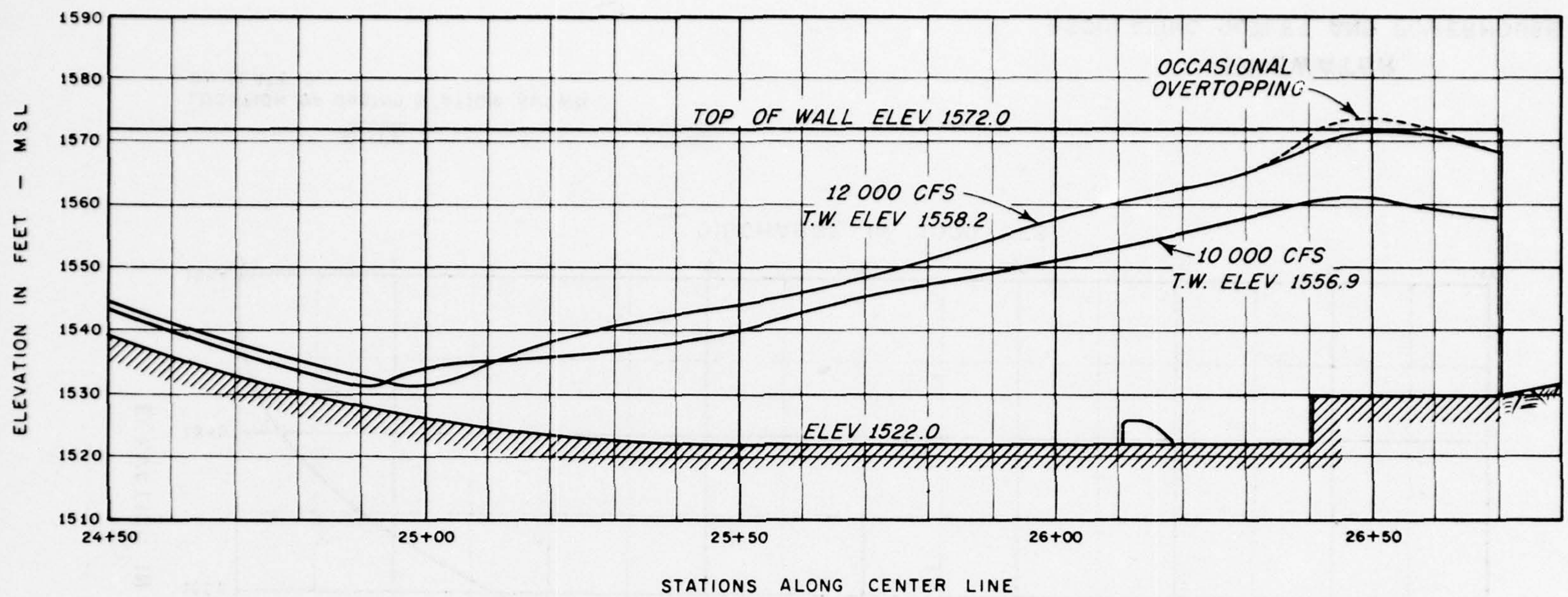
ORIGINAL DESIGN



NOTE

LOCATION OF GAGING STATION SHOWN ON PLATE 2.

TAILWATER
REGULATING OUTLET AND POWERHOUSE



NOTE

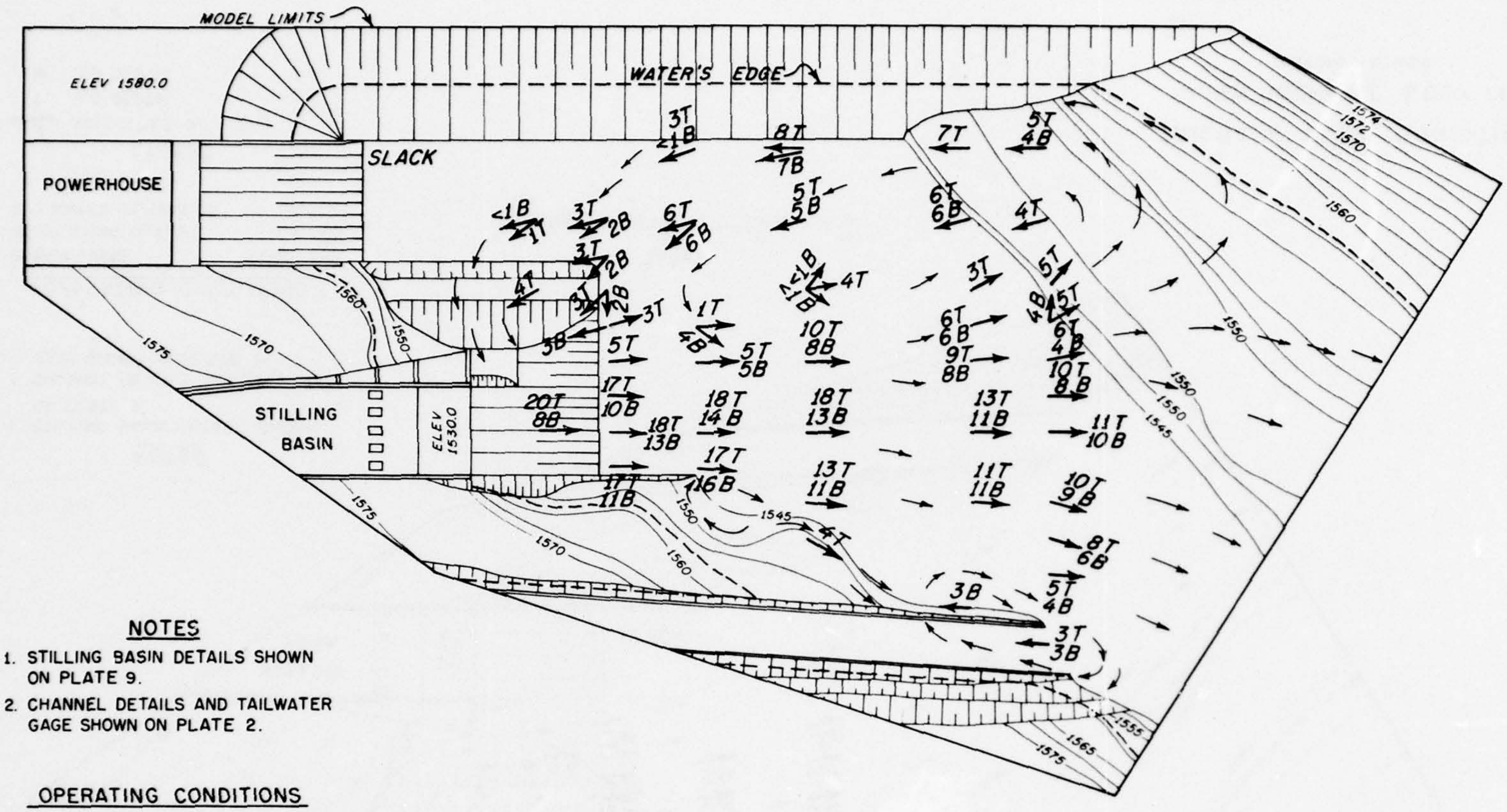
STILLING BASIN DETAILS SHOWN ON PLATE 9.

OPERATING CONDITIONS

NORMAL TAILWATER
POWERHOUSE CLOSED

MAXIMUM WATER-SURFACE PROFILES

LEFT WALL
REGULATING OUTLET STILLING BASIN
ORIGINAL DESIGN

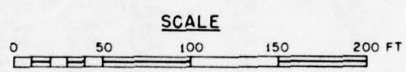


NOTES

1. STILLING BASIN DETAILS SHOWN ON PLATE 9.
2. CHANNEL DETAILS AND TAILWATER GAGE SHOWN ON PLATE 2.

OPERATING CONDITIONS

POWERHOUSE	CLOSED
REGULATING OUTLET	12 000 CFS
TAILWATER ELEVATION	1558.2



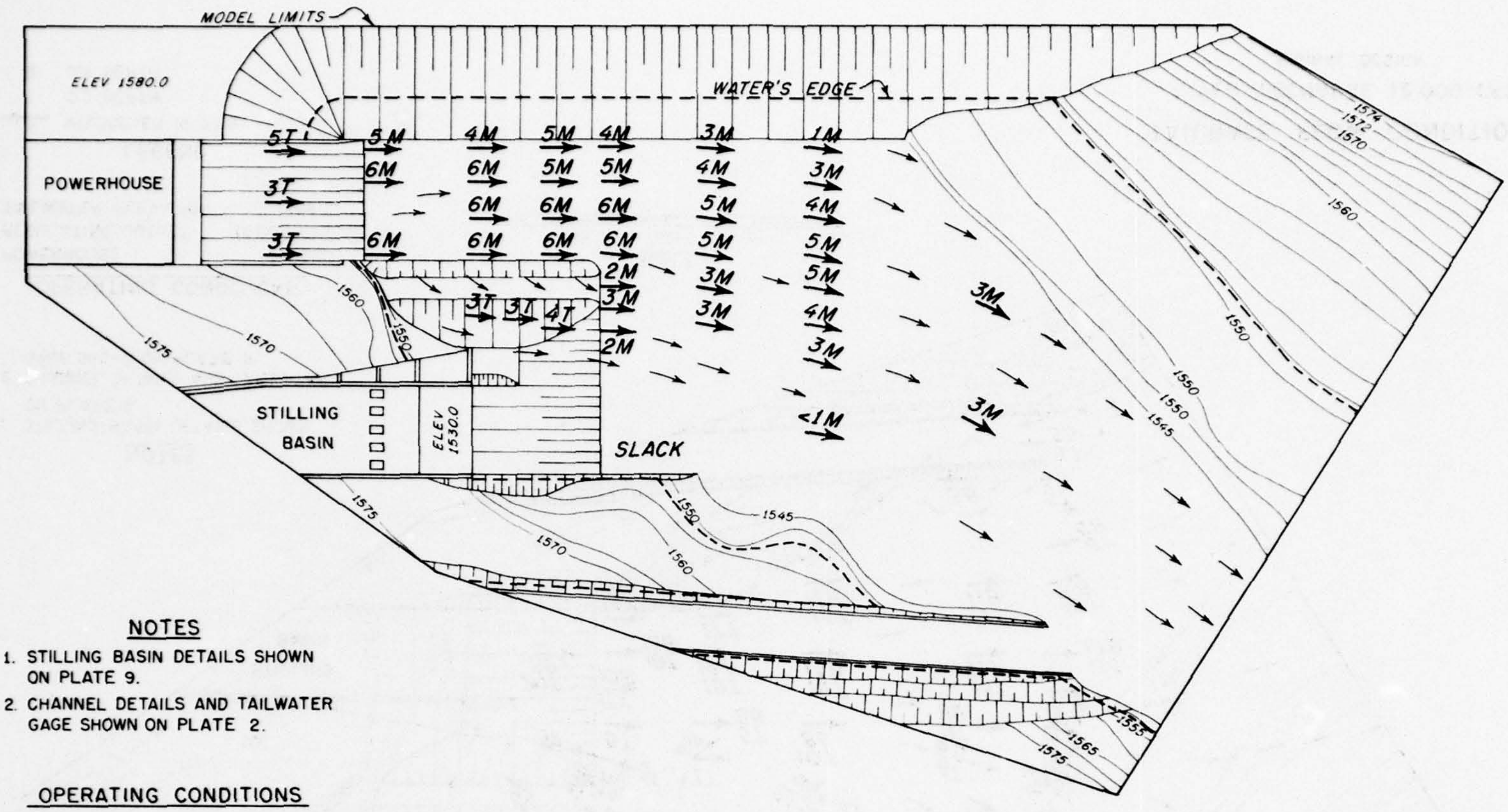
LEGEND

4 VELOCITIES IN FPS
T 0.2 DEPTH
B 0.8 DEPTH

TAILRACE FLOW CONDITIONS

RIVER DISCHARGE 12 000 CFS

ORIGINAL DESIGN



NOTES

1. STILLING BASIN DETAILS SHOWN ON PLATE 9.
2. CHANNEL DETAILS AND TAILWATER GAGE SHOWN ON PLATE 2.

OPERATING CONDITIONS

POWERHOUSE	3 000 CFS
REGULATING OUTLET	CLOSED
TAILWATER ELEVATION	1551.8

LEGEND

4 VELOCITIES IN FPS
T 0.2 DEPTH
M 0.5 DEPTH

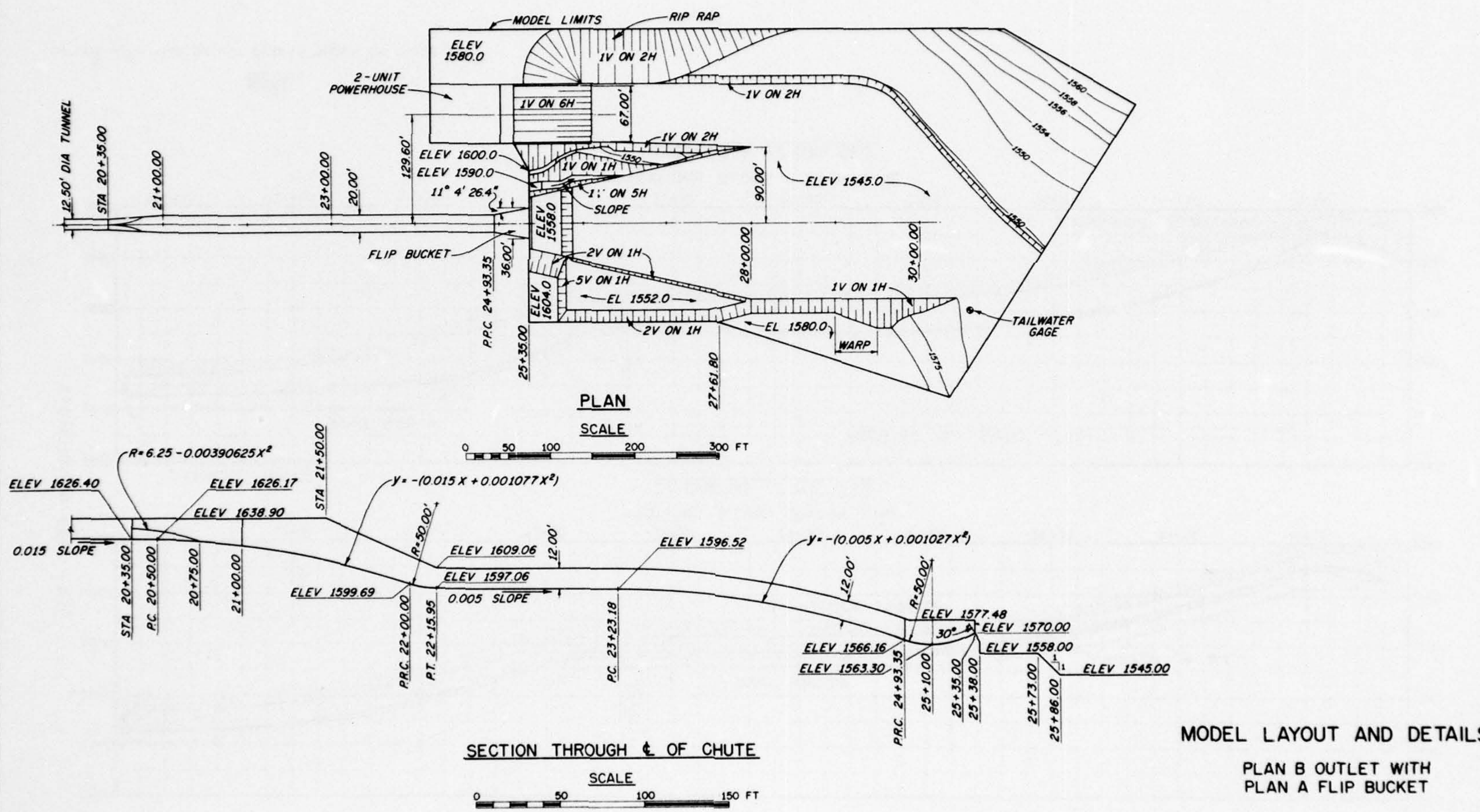
SCALE

0 50 100 150 200 FT

TAILRACE FLOW CONDITIONS

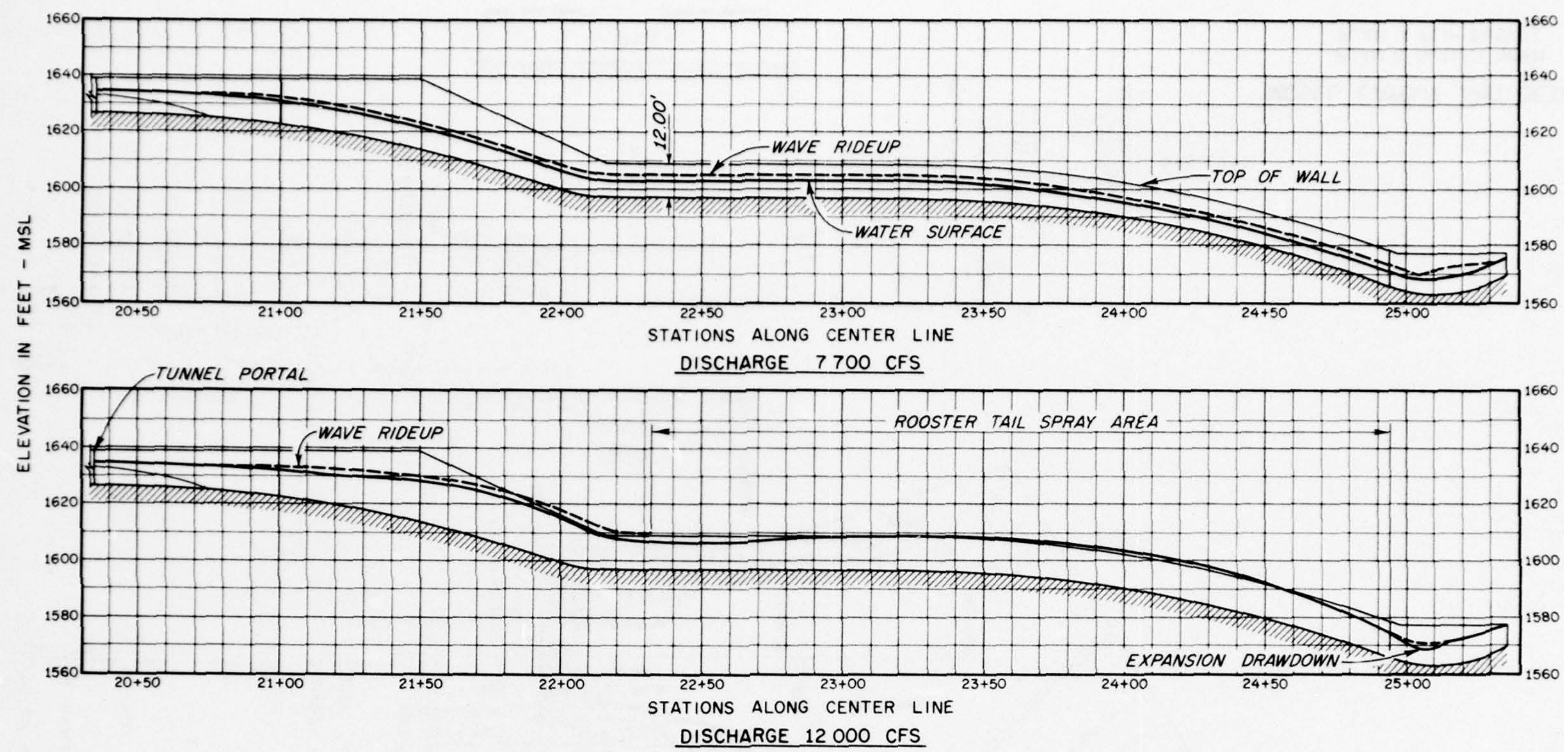
RIVER DISCHARGE 3 000 CFS

ORIGINAL DESIGN



MODEL LAYOUT AND DETAILS

PLAN B OUTLET WITH
PLAN A FLIP BUCKET

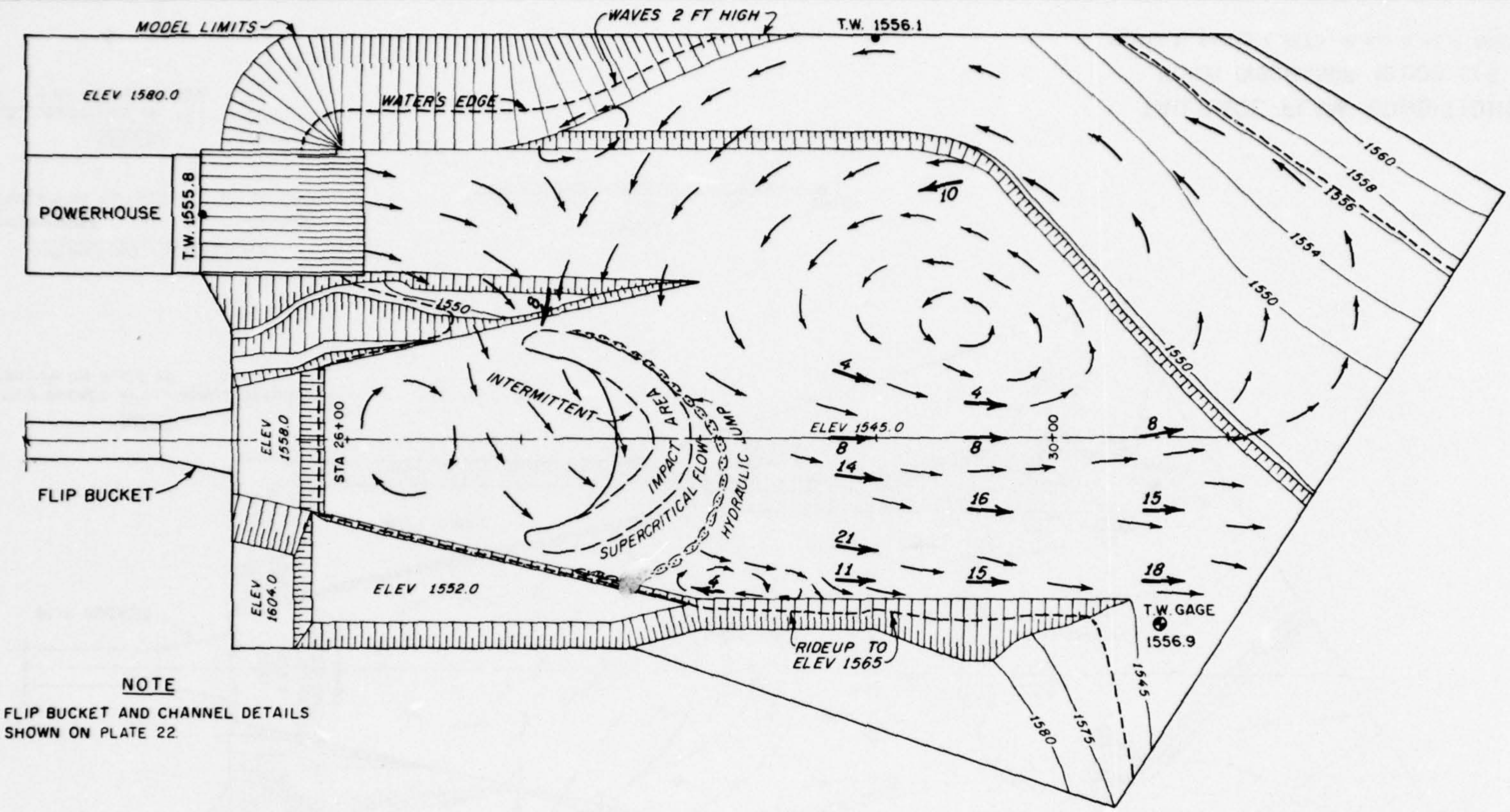


NOTE

OUTLET WITH FLIP BUCKET DETAILS SHOWN ON PLATE 22.

MAXIMUM WATER-SURFACE PROFILES

LEFT WALL
PLAN B OUTLET WITH PLAN A FLIP BUCKET



NOTE

FLIP BUCKET AND CHANNEL DETAILS SHOWN ON PLATE 22.

OPERATING CONDITIONS

POWERHOUSE	2 300 CFS
REGULATING OUTLET	7 700 CFS

SCALE

0 50 100 150 200 FT

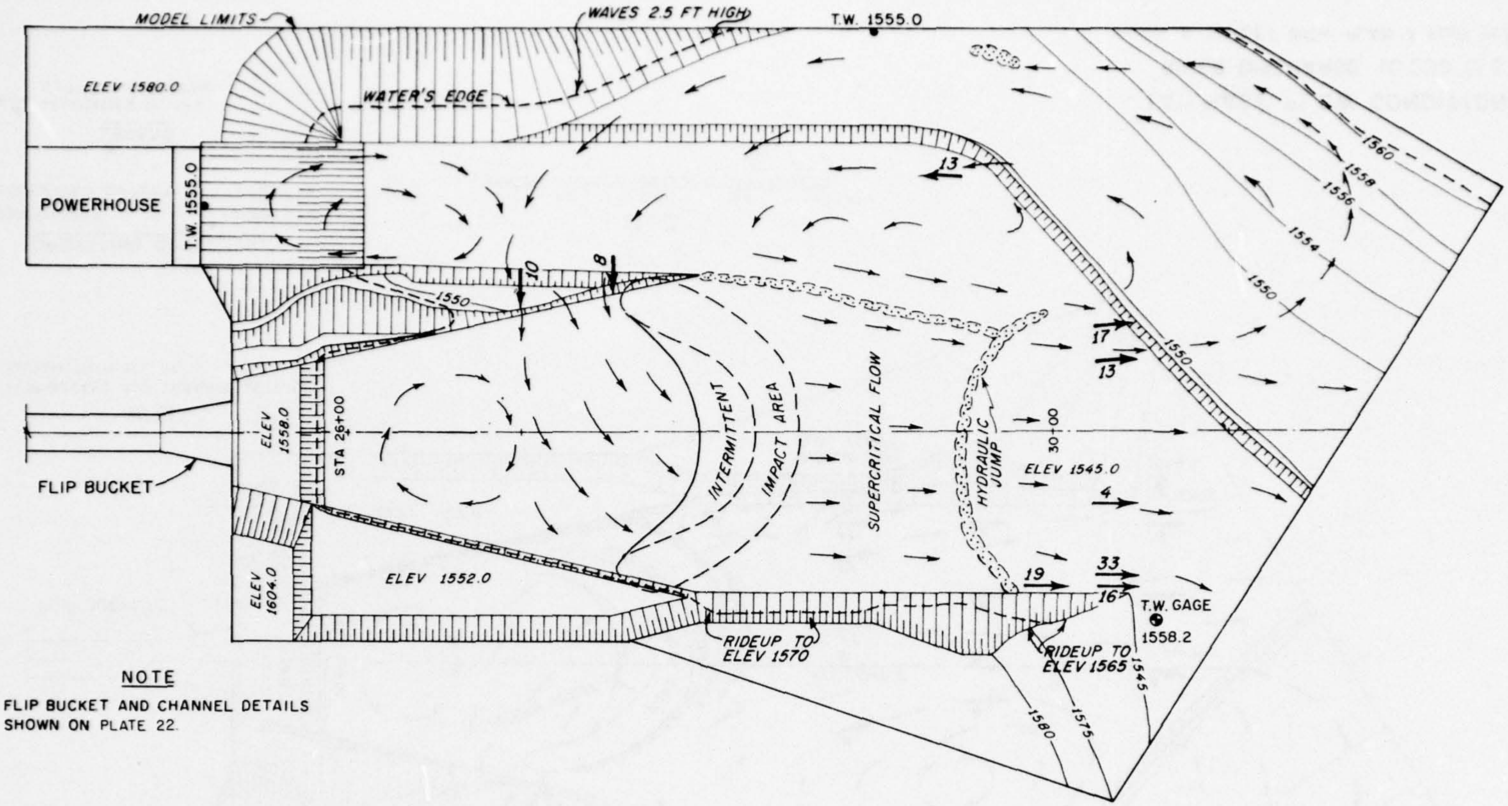
LEGEND

4 VELOCITIES IN FPS 3 FT ABOVE BOTTOM.

TAILRACE FLOW CONDITIONS

RIVER DISCHARGE 10 000 CFS

PLAN B OUTLET WITH PLAN A FLIP BUCKET



NOTE

FLIP BUCKET AND CHANNEL DETAILS SHOWN ON PLATE 22.

OPERATING CONDITIONS

POWERHOUSE	CLOSED
REGULATING OUTLET	12 000 CFS

SCALE

0 50 100 150 200 FT

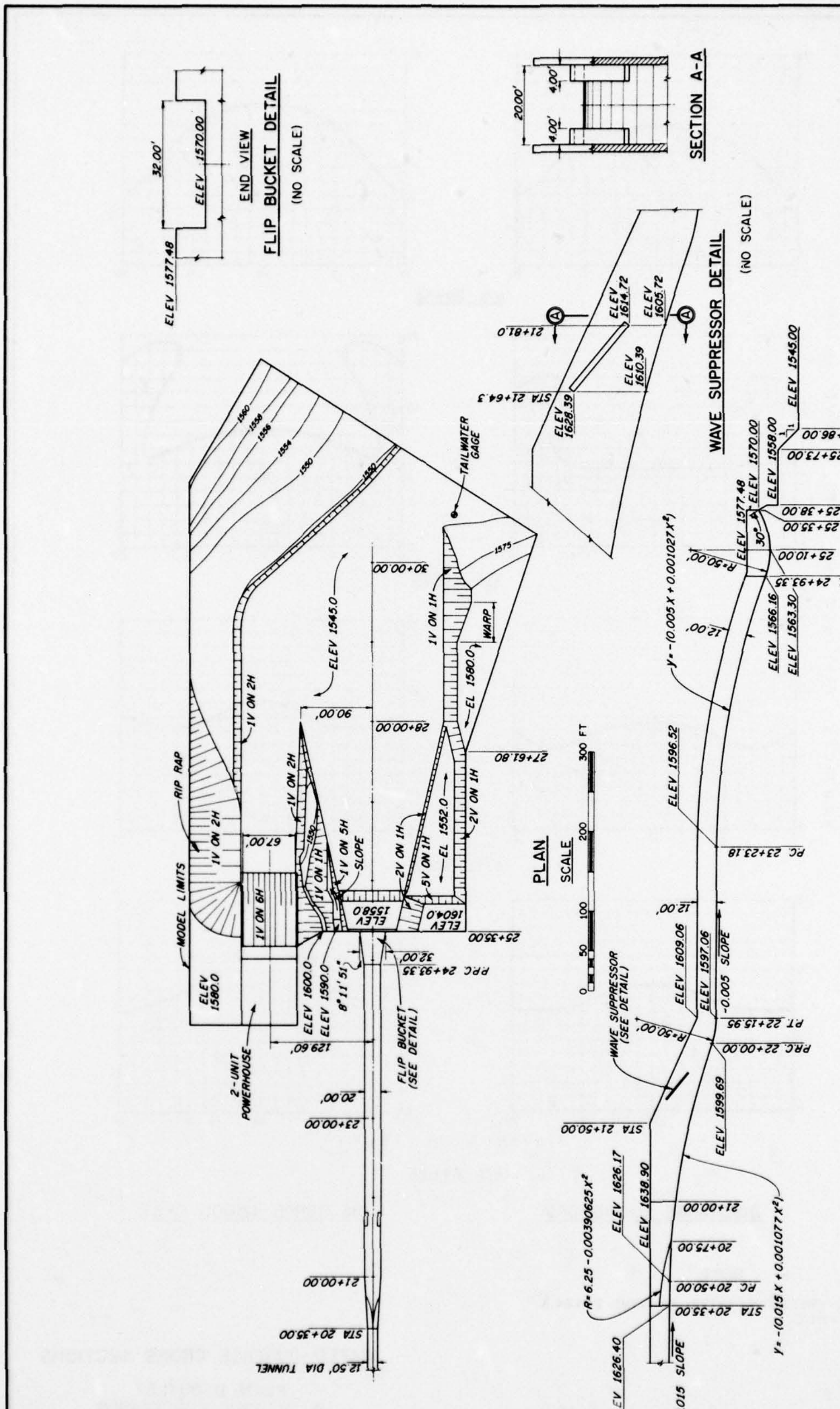
LEGEND

4 VELOCITIES IN FPS 3 FT ABOVE BOTTOM.

TAILRACE FLOW CONDITIONS

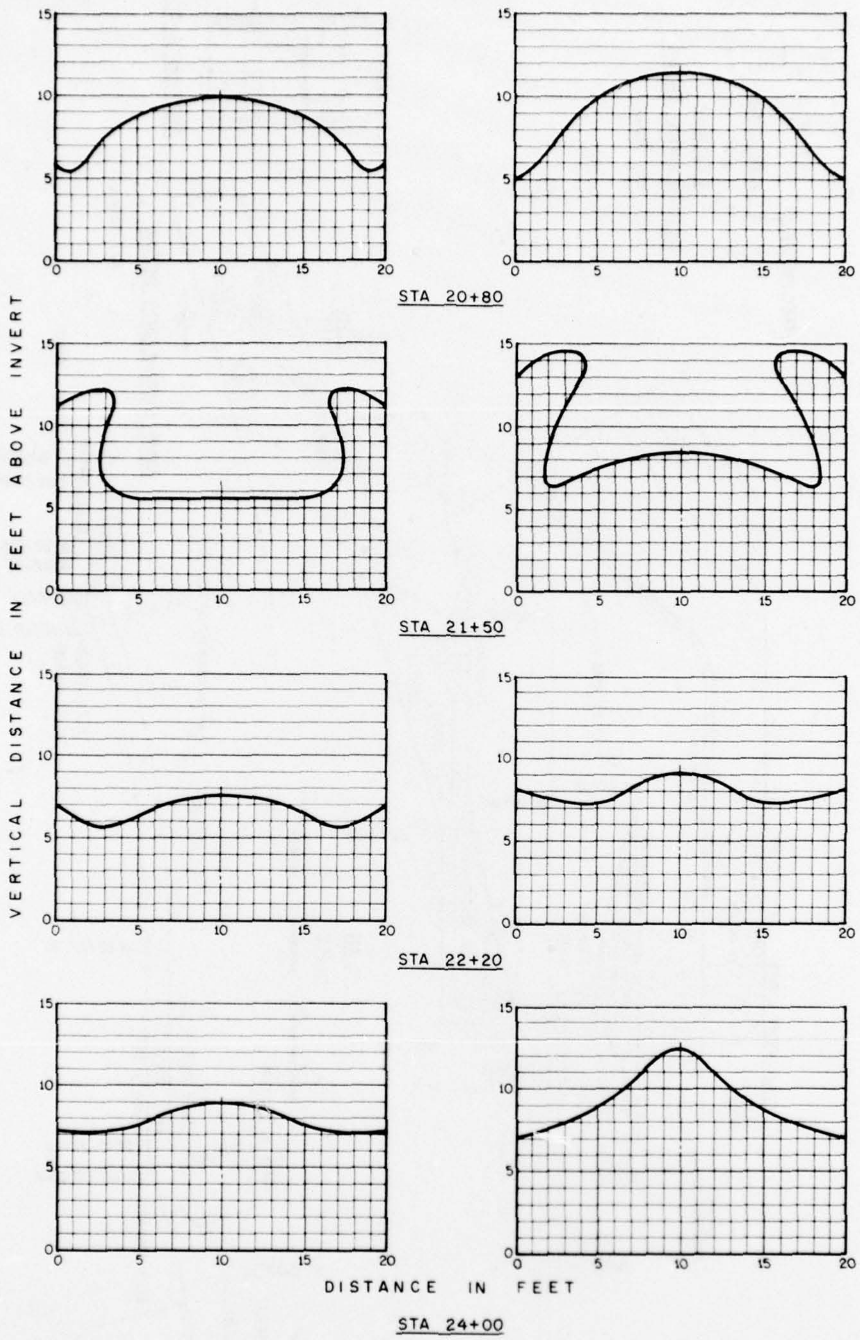
RIVER DISCHARGE 12 000 CFS

PLAN B OUTLET WITH PLAN A FLIP BUCKET



PLAN B OUTLET WITH WAVE SUPPRESSOR

PLAN B FLIP BUCKET



DISCHARGE 10 000 CFS

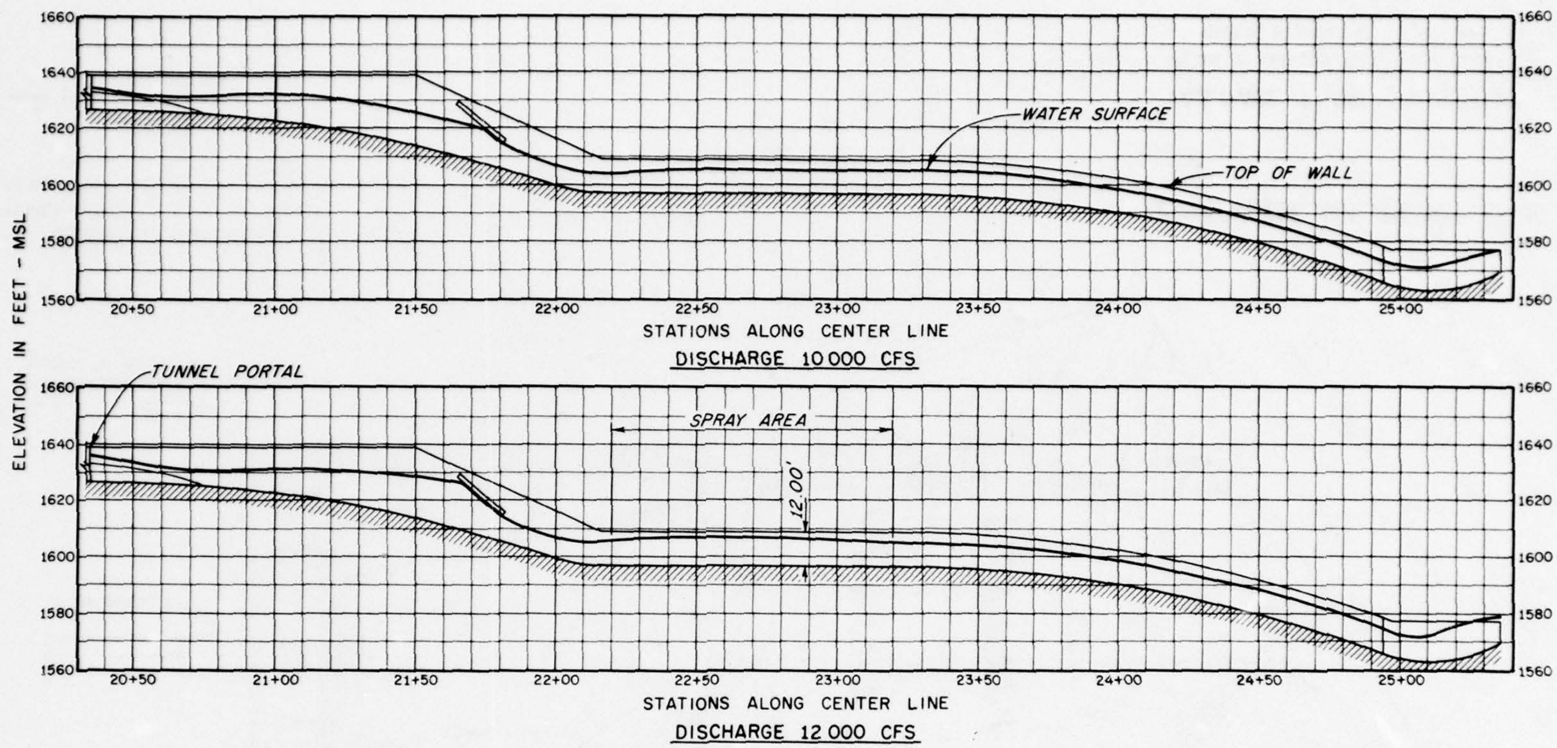
DISCHARGE 12 000 CFS

NOTE

WAVE SUPPRESSOR BETWEEN STATIONS 21+64.3 AND 21+81.0.

WATER-SURFACE CROSS SECTIONS

PLAN B OUTLET
WITH WAVE SUPPRESSOR

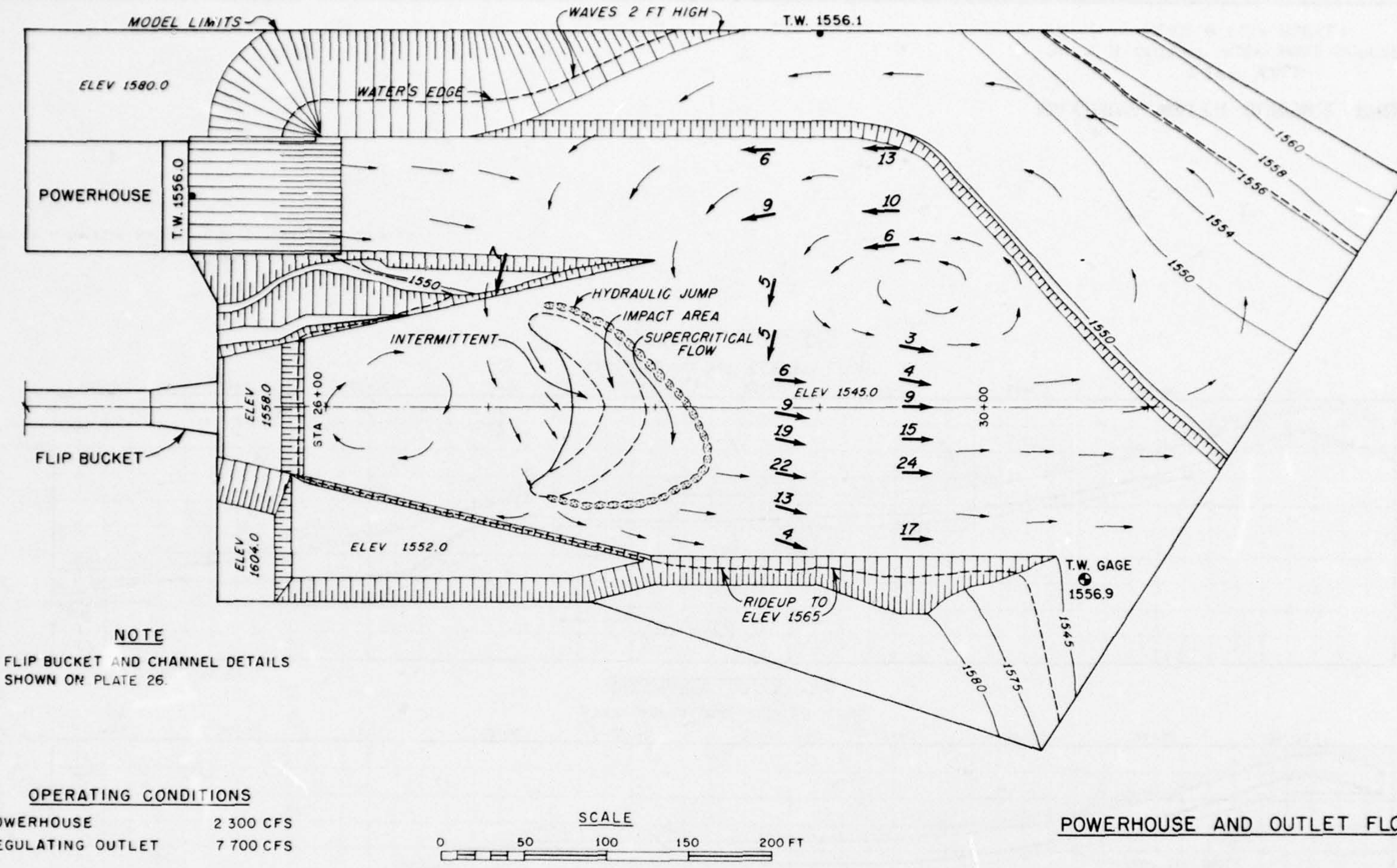


NOTE

OUTLET WITH FLIP BUCKET DETAILS SHOWN ON PLATE 26.

MAXIMUM WATER-SURFACE PROFILES

LEFT WALL
PLAN B OUTLET WITH WAVE SUPPRESSOR
PLAN B FLIP BUCKET



NOTE

FLIP BUCKET AND CHANNEL DETAILS
SHOWN ON PLATE 26.

OPERATING CONDITIONS

POWERHOUSE	2 300 CFS
REGULATING OUTLET	7 700 CFS

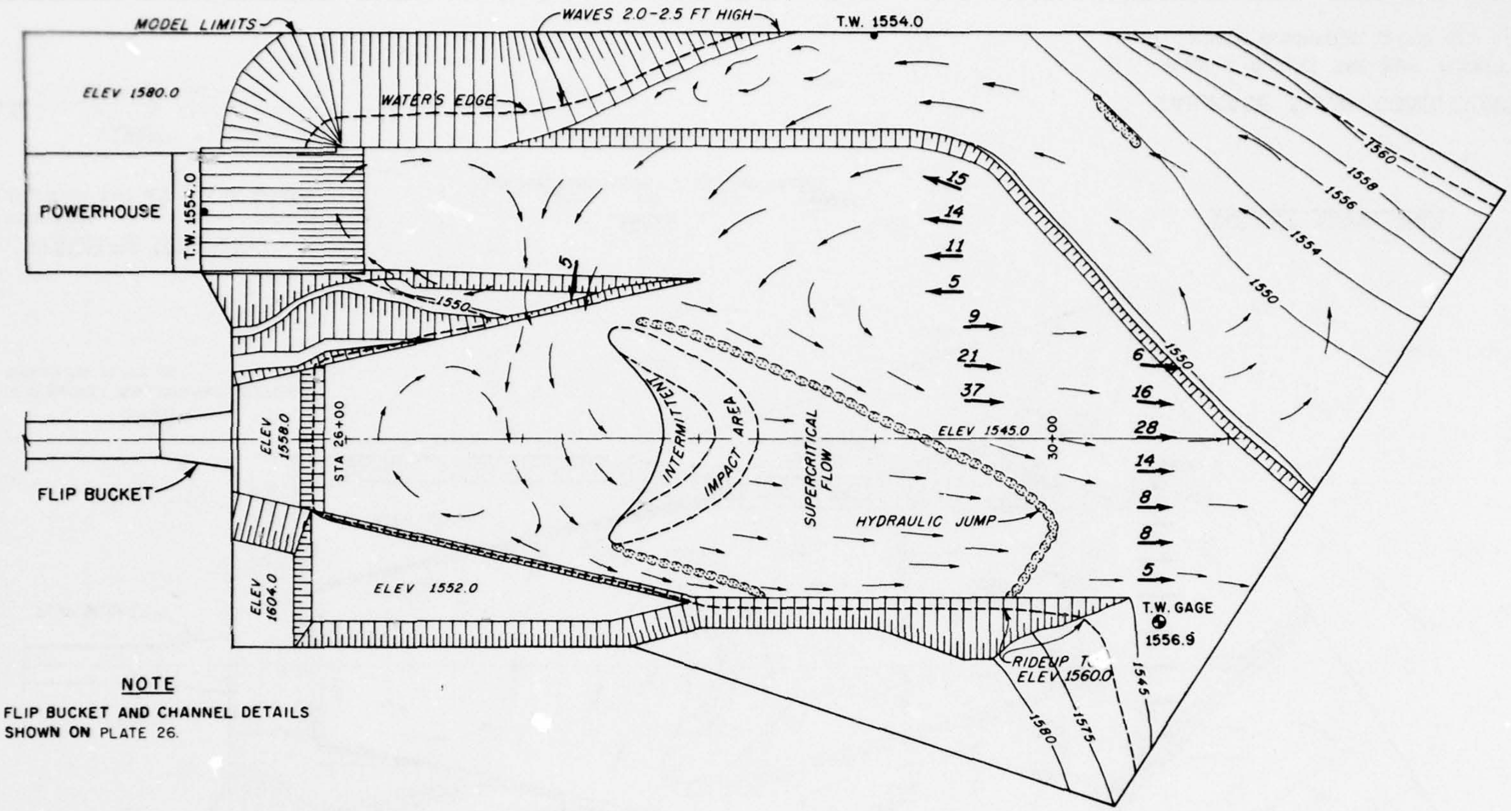
LEGEND

4 ← VELOCITIES IN FPS
3 FT ABOVE BOTTOM

POWERHOUSE AND OUTLET FLOW

TAILRACE FLOW CONDITIONS

PLAN B OUTLET AND FLIP BUCKET
RIVER DISCHARGE 10 000 CFS



NOTE

FLIP BUCKET AND CHANNEL DETAILS SHOWN ON PLATE 26.

OPERATING CONDITIONS

POWERHOUSE	CLOSED
REGULATING OUTLET	10 000 CFS

SCALE

0 50 100 150 200 FT

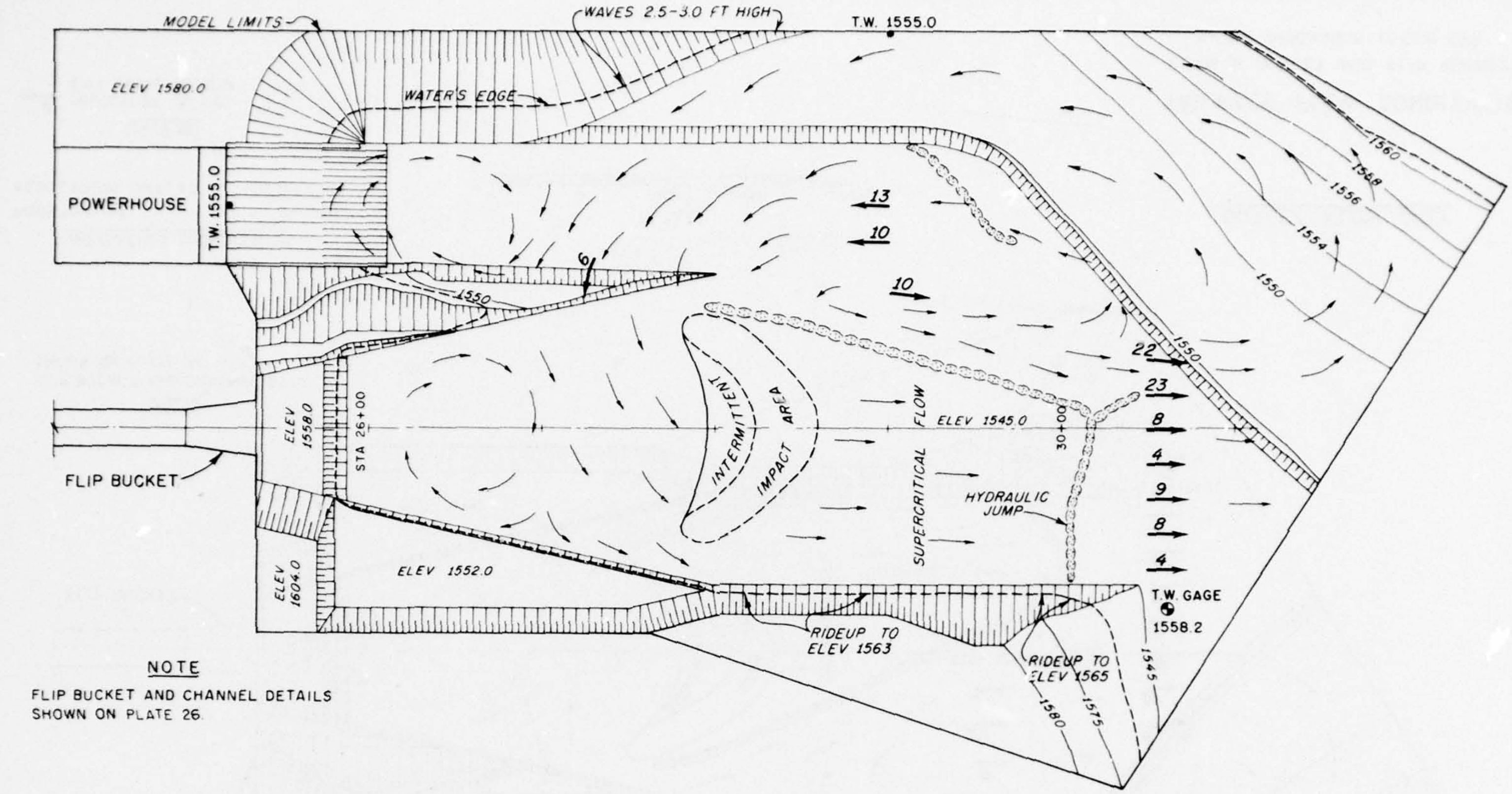
LEGEND

4 VELOCITIES IN FPS 3 FT ABOVE BOTTOM

OUTLET FLOW ONLY

TAILRACE FLOW CONDITIONS

PLAN B OUTLET AND FLIP BUCKET
RIVER DISCHARGE 10 000 CFS



NOTE

FLIP BUCKET AND CHANNEL DETAILS SHOWN ON PLATE 26.

OPERATING CONDITIONS

POWERHOUSE	CLOSED
REGULATING OUTLET	12 000 CFS

LEGEND

4 VELOCITIES IN FPS 3 FT ABOVE BOTTOM

SCALE

0 50 100 150 200 FT

OUTLET FLOW ONLY

TAILRACE FLOW CONDITIONS

PLAN B OUTLET AND FLIP BUCKET
RIVER DISCHARGE 12 000 CFS